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NONDESTRUCTIVE EVALUATION OF METALLIZED TAPE BONDS FORMED BY TAPE AUTOMATED BONDING (TAB)

Sonoscan, Inc.

Lawrence W. Kessler, Janet E. Semmens, Frank J. Cichanski

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This contract was one of two awarded to develop a new test for the nondestructive evaluation of metallurgical tape bonds which interconnect a VLSI/VHSIC chip to a microcircuit package or substrate. The process of forming the interconnections is known as Tape Automated Bonding, or TAB. The accepted standard of nondestructive wire pull testing is difficult or impossible to apply to TAB and furthermore, it may be subject to artifacts which cause severe interpretation problems. Experiments performed in this study demonstrated the utility of Scanning Laser Acoustic Microscopy (SLAM), in evaluating TAB bonds both at the site of the IC chip and at the site of the interconnection package and the results show excellent correlation to bond quality. Proposed additions to MIL-STD-883 are included in the report.

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EVALUATION

The objective of this effort was to develop a Non Destructive Evaluation (NDE) technique and accept/reject criteria for the assessment of the quality of metallurgical bonds formed between a tape interconnect structure and the chip and package being interconnected. The development of tape interconnect structures and Tape Automated Bonding (TAB) technologies have received increased emphasis with the availability of VLSI/VHSIC microcircuits containing I/O terminations extending from one hundred to four hundred connections. The traditional method of using aluminum or gold wires to accomplish the electrical interconnections is being replaced by the polyimide tape and TAB structures. The use of these tape and TAB structures have introduced a potential reliability problem to the VLSI microcircuits designed to operate in the severe military environment. There is no currently available nondestructive means to assess the structural integrity of the metallurgical bonds formed.

Sonoscan Inc. was founded in 1973 to further develop methods of applying Scanning Laser Acoustic Microscopy (SLAM) as a vital tool in developing product quality and reliability. Acoustic Microscopy surpasses conventional ultrasonic inspection techniques in resolution, detectability, image magnification and speed of scan and produces images of features beneath the surface of a sample. Because ultrasonic energy requires continuity of materials to propagate, internal defects such as voids, cracks and delaminations interfere with the transmission and/or reflection of ultrasound signals.

Under contract funding Sonoscan investigated a matrix of TAB inner and outer lead devices with a built-in range of quality. Each bond interface was documented acoustically and then pull-tested to develop a database upon which to formulate a specific test method according to the criteria in the Statement of Work. The data demonstrated good correlation between the degree of bonding and correlative tests (destructive). This investigation was performed with acoustic microscopy techniques which were adapted to TAB. In the case of inspecting the Inner Lead Bonds (ILB) to silicon and the Outer Lead Bonds (OLB) to a ceramic substrate, the SLAM imaging was found to be the optimum method for detecting fine laminar defective bonds in the near subsurface zone.

The contractor successfully developed and documented a TAB bond integrity test procedure that was written in the MIL-STD-883 format. For future applications, further adjustments and modifications will continue to be made to the existing Scanning Laser Acoustic Microscopy (SLAM) system as the need arises and as contractor requirements are documented after field use of this TAB bond inspection tool.

Patricia S. Speicher

PATRICIA S. SPEICHER
Project Engineer

SUMMARY

A new test is proposed for the nondestructive evaluation of metallurgical tape bonds which interconnect a VLSI/VHSIC chip to a microcircuit package or a substrate. The process of forming the interconnections is known as Tape Automated Bonding, or TAB. The accepted standard of nondestructive wire pull testing is difficult or impossible to apply to TAB and furthermore, it may be subject to artifacts which cause severe interpretation problems. Experiments performed in this study demonstrated the utility of Scanning Laser Acoustic Microscopy (SLAM), in evaluating TAB bonds both at the site of the IC chip, and at the site of the interconnection package, and the results show excellent correlation to bond quality. Proposed additions to MIL-STD-883 are included in the report.

PREFACE

This study was conducted under Contract F30602-86-C-0050 by Sonoscan, Inc., Bensenville, IL. The contract was administered under the technical direction of Mr. Eugene C. Blackburn and Ms. Patricia Speicher of the Rome Air Development Center, Griffiss Air Force Base, NY.

The results of a two year study to develop a nondestructive test for metallurgical tape bonds formed by Tape Automated Bonding (TAB) are reported here. In the approach, Scanning Laser Acoustic Microscopy (SLAM) was adapted to the special needs of TAB. A matrix of samples having a range of bond qualities was obtained and the samples were used to establish evaluation parameters. New test methods are proposed for inclusion in MIL-STD-883.

The Sonoscan Project Manager was Dr. Lawrence W. Kessler and engineers who contributed to the project were Ms. Janet E. Semmens and Mr. Frank Cichanski. The cooperation of GTE Communications Systems, Inc., Delco Electronics, and MESA Technology, is appreciated with regards to samples used in this project.

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For the purposes of brevity, the following listing employs these codes:

all ILBs	(all solder TAB Inner Lead Bond samples)
SS ILBs	(solder TAB Inner Lead Bond samples pull tested by Sonoscan using a hook pull test implementation)
GTE ILBs	(solder TAB Inner Lead Bond samples pull tested by GTE using a tweezer pull test implementation)
all OLBs	(all solder TAB Outer Lead Bond samples)
SS OLBs	(solder TAB Outer Lead Bond samples pull tested by Sonoscan using a hook pull test implementation)
GTE OLBs	(solder TAB Outer Lead Bond samples pull tested by GTE using a tweezer pull test implementation)
MESA ILBs	(gold-gold thermocompression and gold-tin eutectic TAB Inner Lead Bond Samples pull tested by MESA using a hook pull test implementation)
smoothed x0	(data NOT subjected to neighboring-point averaging for purposes of smoothing; i.e. NOT smoothed)
smoothed x2	(data employing "smoothing" with up to 2nd ranked neighboring points, for cosmetic purposes)
smoothed x8	(data employing "smoothing" with up to 8th ranked neighboring points, for removal of the "corner effect" spatial frequency)

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I. INTRODUCTION

A. Statement of the Problem

In the process known as Tape Automated Bonding, or TAB, metallurgical bonds are formed between a tape interconnect structure and an integrated circuit. Bonds are also formed between the interconnect structure and the external electrical circuit or the device package. TAB is receiving increased emphasis in VLSI and VHSIC microcircuits because of its ability to accommodate a very high population density of input/output (I/O) terminations on the chip. Devices having more than 300 I/Os and lead pitch of 4 mils are not uncommon. In comparison with conventional wire bonding, whose interconnections are made one at a time, TAB leads are usually gang bonded.

In high reliability situations for conventional wire bonded ICs, nondestructive pull tests are required to be performed. Here, a tiny hook is aligned under each of the wire loops and a carefully limited pull force is applied to test the integrity of each bond. Bonds that do not break under the applied force are considered good. With high density TAB, however, pull tests are either difficult or nearly impossible to perform, or if performable, are subject to significant inaccuracies. This is usually due to the very tight geometry of TAB which restricts the use of a hook and to a number of geometrical factors. For example, the TAB leads are much larger in cross-section than the wire used in wire bonding, they are rectangular in cross-section, the spacing between the leads is quite small leaving no room to insert a hook and with the flat geometry of TAB, there is no loop on the lead for a hook to grab. Furthermore, when a round hook grabs a rectangular shaped lead, the pull force may have vectors which twist the lead while pulling it up, thereby causing a tearing motion and consequent low apparent strength. Visual inspection, scanning electron microscope inspection, and electrical tests are poor indicators of bond quality. The problem is to develop a test method to assure the integrity of TAB bonds nondestructively.

The effort reported here employs Scanning Laser Acoustic Microscopy, SLAM, a well established technique for nondestructive testing, to inspect, characterize and ascertain the quality of TAB bonded leads to the IC chip and to a ceramic substrate package. These bonds are referred to as inner lead bonds (ILBs) and outer lead bonds (OLBs), respectively. In an earlier study,[1] it was shown that 100 MHz SLAM had the potential of determining the quality of Au-Au thermocompression bonds on hybrid circuits. The data obtained correlated well with pull strength which was subsequently measured destructively. The evaluation of bonds by SLAM does not depend upon the type of bond, e.g. Au-Au, Au-Sn, or Pb-Sn, nor does it depend upon the type of leads or the plating, e.g. bare Cu, Sn plated, Au plated, etc. In this study, the emphasis was placed upon Pb-Sn bonds, although examples of Au-Au thermocompression and Au-Sn eutectic bonds are also included. This report documents the use and effectiveness of SLAM to determine the quality of TAB bonds of good, bad, and marginal properties. The data base in this report consists of 1152 OLBs and 2235 ILBs. This report concludes with a series of probability curves which predict the quality of a bond based upon SLAM measurements. Proposed test methods are included as an Appendix for MIL-STD-883.

B. Acoustic Microscopy

1) Review of Technology and Applications

Acoustic Microscopy is the general term applied to high resolution, high frequency ultrasonic inspection techniques which produce images of features beneath the surface of a sample. Because ultrasonic energy requires continuity of materials to propagate, internal defects such as voids, delaminations and cracks interfere with the transmission and/or reflection of ultrasound signals. Air is a very poor conductor of ultrasound, therefore gaps within or between samples are easily visualized by the localized changes in the ultrasound. Acoustic microscopy is now becoming recognized as a valuable tool for nondestructive inspection of electronic components and materials characterization. Most of the better knkown applications are related to microelectronic packaging, such as plastic molding compound adhesion on ICs, die attach evaluation per MIL-STD-883, method 2030, multilayer ceramic capacitors, per MIL-C-123 and hybrid component bond evaluation.

There are three different methods that are considered to belong to the acoustic microscopy field:

1. The Scanning Laser Acoustic Microscope (SLAM), which was first reported by Korpel, Kessler, and Palermo in 1970.(2)

2. The Scanning Acoustic Microscope (SAM) which was first reported reported by Lemons and Quate in 1974.(3)

3. The improved versions of C-Scan instruments which are also referred to as C-Mode Scanning Acoustic Microscopes (C-SAMs).(4)

Each of these methods has a specific range of usefulness and, most often the methods are noncompetitive with regards to applications. That is, only one of them will be best suited for a particular inspection problem.

As a general comparison between the methods, the SLAM is a transmission mode instrument that creates true real-time images of a sample throughout its entire thickness. In operation, ultrasound is introduced to the bottom surface of the sample by a piezoelectric transducer and the transmitted wave is detected on the top side by a rapidly scanning laser beam. The other two types of microscopes are both reflection mode instruments that use a transducer with an acoustic lens to focus the wave at or below the sample surface. The transducer is mechanically translated (scanned) across the sample in a raster fashion to create the image. SAM is designed for very high resolution images of the surface and near surface region of a sample. Penetration depth is limited however, to one wavelength of sound. For example, at 200 MHz the penetration limit is about 10 microns. C-SAM is designed for moderate penetration into a sample. It employs a pulse-echo transducer and the specific depth of view can be electronically gated. C-SAM can image several millimeters down into most samples and is ideal for analyzing at a specific depth. Because of a very large top surface reflection from the sample, C-SAM is not effective in the zone immediately below the surface. A more detailed discussion of acoustic microscopy techniques follows:

a) SLAM Operation

A collimated beam of continuous wave ultrasound at frequencies up to several hundred megahertz is produced by a piezoelectric transducer located beneath the sample as illustrated in Figure 1.1. Since this ultrasound cannot travel through air (making it an excellent tool for crack, void, and disbond detection) a fluid couplant is used to bring the ultrasound to the sample. Distilled water, spectrophotometric grade alcohol, or other inert fluids may be used depending upon the concerns for sample contamination. When the ultrasound travels through the sample, the wave is affected by the homogeneity of the material. Wherever there are anomalies, the ultrasound is differentially attenuated and the resulting image reveals characteristic light and dark features which correspond to the localized acoustic properties of the sample. Multiple views can be made, as in x-ray, to determine the specific depth of a defect.

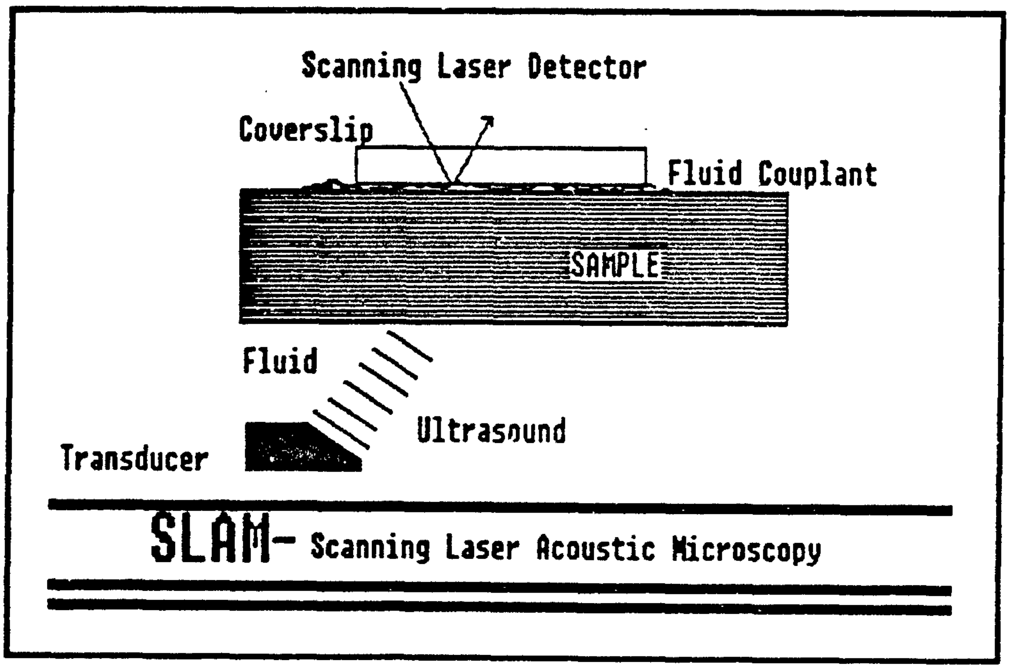


Figure 1.1. Block diagram of the Scanning Laser Acoustic Microscope - a through transmission real-time technique that employs a plane wave piezoelectric transducer to generate the ultrasound and a focused laser beam as a point source detector of the ultrasonic signal.

A laser beam is utilized as an ultrasound detector by means of sensing the infinitesimal displacements (rippling) at the surface of the part created by the ultrasound. In TAB samples (which do not have polished, optically reflective surfaces) a mirrored plastic block, or coverslip, is placed in close proximity to the surface and is acoustically coupled with fluid. The laser is focused onto the coverslip, which has a corresponding ripple pattern to the sample surface. The SLAM images are produced in real-time, i.e., 30 pictures per second, and are displayed on a high resolution video monitor. Note: In contrast to other less accurate uses of the term "real-time" in industry today, SLAM can be used to watch events as they occur, such as a crack propagating under an applied stress. The images produced by SLAM are shadowgraph mode images of structure throughout the thickness of the sample. This has the distinct advantage, like x-ray, of simultaneously viewing the entire thickness of the sample. In situations where it is necessary to focus on one specific plane, holographic reconstruction[5,6] of the SLAM data can be employed.

The SLAM images also provide useful and easy to interpret quantitative data about the sample. For example, the brightness of the image corresponds to the acoustic transmission level. By removing the sample and restoring the image brightness level with a calibrated electrical attenuator placed between the transducer and its electrical driver, precise insertion loss data can be obtained.[7,8] Using the acoustic interference mode, the velocity of sound can be measured in each area of the sample.[9,10] When these data are used to determine regionally localized acoustic attenuation loss, modulus of elasticity, etc., the elastic microstructure is well characterized.

The simplest geometries for SLAM imaging are flat plates or discs. However, with proper fixturing, complex shapes and large size samples can also be accommodated. For example, tiny hybrid electronic components, large 10"x10" metal plates, aircraft turbine blades and ceramic engine cylinder liner tubes have been examined with SLAM.

b) C-SAM Operation

The C-SAM, or C-Mode Scanning Acoustic Microscope, is primarily a pulse-echo (reflection type) microscope that generates images by mechanically scanning a transducer in a raster pattern over the sample. A focused spot of ultrasound is generated by an acoustic lens assembly at frequencies typically ranging from 10 - 100 MHz. A schematic diagram is shown in Figure 1.2. The ultrasound is brought to the sample by a coupling medium, usually water or an inert fluid. The angle of the rays from the lens is generally kept small in order that the incident ultrasound does not exceed the critical angle of refraction between the fluid coupling and the solid sample. Note that the focal distance into the sample is shortened considerably by the liquid-solid refraction. The transducer alternately acts as sender and receiver, being electronically switched between the transmit and receive modes. A very short acoustic pulse enters the sample and return echoes are produced at specific interfaces within the part. The return times are a function of the distance from the interface to the transducer. An oscilloscope display of the echo pattern, known as an A-Scan, clearly shows these levels and their time-distance relationships from the sample surface. This provides a basis for investigating anomalies at specific levels within a part. An electronic gate selects information from a specific level to

be imaged while it excludes all other echoes. The gated echo brightness-modulates a CRT which is synchronized with the transducer position.

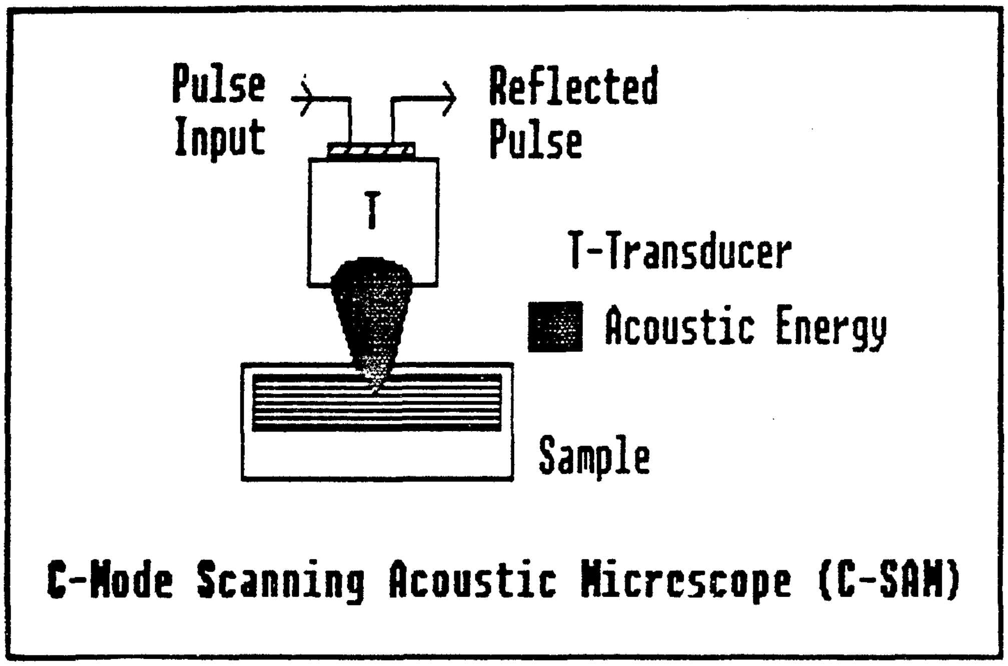


Figure 1.2. Block diagram of the C-Mode Scanning Acoustic Microscope-a reflection, pulse-echo technique that employs a focused transducer-lens to generate and receive the ultrasound signals beneath the surface of the sample.

In comparison with older conventional C-Scan type instruments which produce a binary gray scale output on thermal paper when a signal exceeds an operator selected threshold, the C-SAM output is displayed in full grey scale. Furthermore, in the Sonoscan C-SAM, the images are also color-coded with echo polarity information.[11] That is, positive echos which arise from reflection from a higher impedance interface are displayed in a grey scale having one color scheme, while negative echos, from reflections off of lower impedance interfaces are displayed in a different color scheme. The purpose of this is to be able to quantitatively determine the nature of the interface within the sample. The Sonoscan C-SAM is further differentiated from conventional C-Scan equipment by the speed of scan. Here, tne transducer is positioned by a very fast

mechanical scanner which produces images in tens of seconds instead of tens of minutes for scan areas, the size of an integrated circuit.
With regards to the depth zone of a sample that is accessible to C-SAM techniques, it is well known that the large echo from a liquid-solid interface (the top surface of the sample) masks out small echos which may occur near the surface within the solid material. This characteristic is known as the "dead zone" and its size is usually on the order of a few wavelengths of sound or more. Far below the surface, the maximum depth of penetration is determined by the attenuation losses in the sample and also by the geometric refraction of the acoustic rays which shorten the lens focus by the solid material. Therefore, depending upon the depth of interest within a sample, a proper transducer and lens must be employed.

c.) SAM Operation

The SAM, or Scanning Acoustic Microscope, is primarily a reflection type microscope that generates very high resolution images of surface and near surface features of a sample by mechanically scanning a transducer in a raster pattern over the sample. A diagram of this system is shown in Figure 1-3.

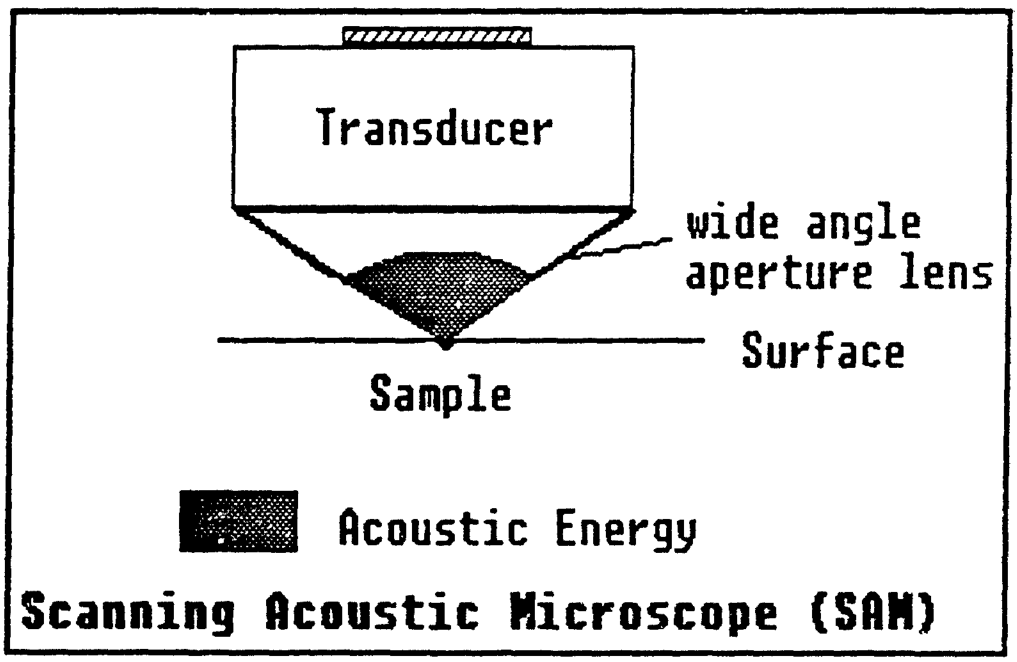


Figure 1.3. Block diagram of the Scanning Acoustic Microscope - a reflection mode technique that interrogates the surface zone of a sample.

In contrast to C-SAM, a more highly-focused spot of ultrasound is generated by a very wide angle acoustic lens assembly at frequencies typically ranging from 100 - 2000 MHz. The angle of the sound rays is well beyond the critical cut-off angle, so that there is essentially no wave propagation into the material, other than an evanescent wave which reaches to about one wavelength depth below the surface. Like the other techniques, the ultrasound is brought to the sample by a coupling medium, usually water or an inert fluid. The transducer alternately acts as sender and receiver, being electronically switched between the transmit and receive modes. However, instead of a short pulse of acoustic energy, a long pulse is directed towards the sample. There is no range gating possible as in C-SAM due to the system design. The returned signal level is determined by the material elastic properties at the near-surface zone. The returned signal level modulates a CRT which is synchronized with the transducer position. In this way images are produced in a raster scan on the CRT. Similar to C-SAM, complete images are produced in about 10 seconds. With the SAM technique operating at very high frequencies, it is possible to achieve resolution nearing that of a conventional optical microscope. This technique is employed in much the same way an optical microscope is employed with the important exception that the information obtained relat... to elastic properties of the material.

2) Consideration for TAB Imaging

Figure 1.4 illustrates the zones of application for all three types of acoustic microscopy methods that are available commercially and are employed by industry. The differences are substantial with regards to their potential for TAB inspection. In the SAM technique, because of the high numerical aperture of the lens the acoustic energy is beyond the critical angle of refraction and does not penetrate far enough below the surface of the TAB lead to detect the bond. The surface texture of the tape lead also produces highly textured features with strong contrast which mask the subsurface detail. In addition, the distance between the lens and the top surface of the sample is extraordinarily critical. For the range of distances which are less than the focal length, there are alternating image contrast reversals in the image which make it very difficult to obtain uniform images from lead to lead on the same sample. This high sensitivity to focus has very good application for materials characterization on thin films and samples which have polished surfaces. The applications of SAM appear to be more suitable for acoustical metallurgy rather than for TAB bond evaluation.

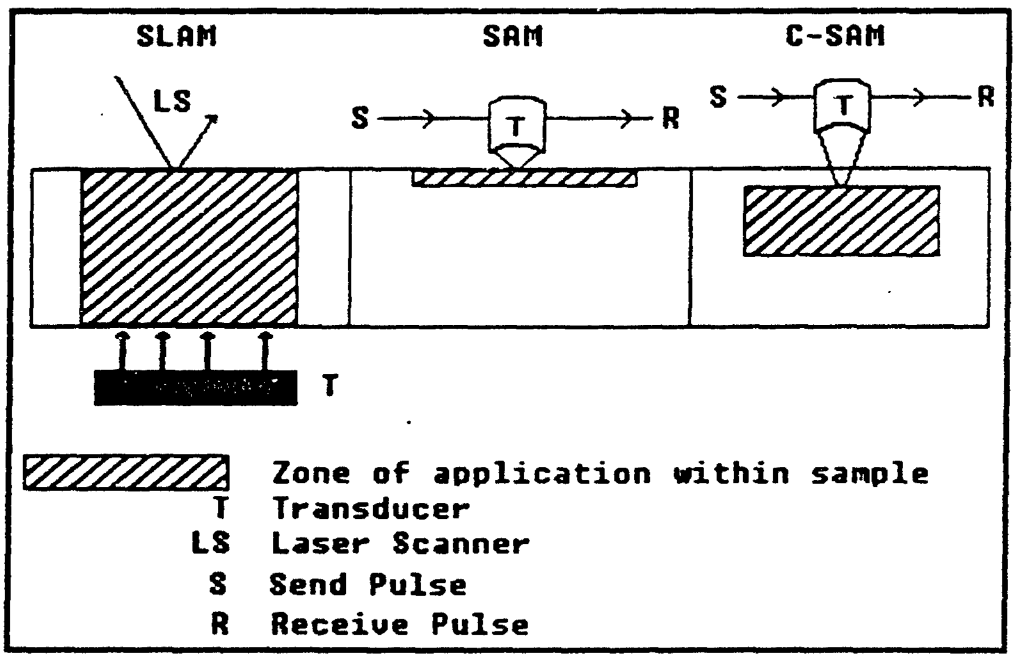


Figure 1.4. Simplified comparison of three acoustic microscopy techniques and in particular their zones of application within a sample.

In the C-SAM technique, there is a "dead zone" below the top surface of the sample within which echos are masked out. TAB leads with thicknesses from 0.5 - 2 mils have bond zones located in exactly the wrong place. In addition, at reasonable frequencies that are employed in C-SAMs, the wavelength of sound is long compared with the lead thickness, thereby precluding time separation of echoes needed to separate the front and back surfaces of the TAB lead.

With respect to the SLAM technique, the depth zone of application does not have the restrictions of the other methods and therefore SLAM appears to be optimum for nondestructive testing of TAB. Delamination anywhere throughout the depth of the sample will cause severe attenuation of the ultrasound, for example, at the lead-bump interface, bump-bondpad interface, bondpad-chip (or substrate) interface, and including delamination of the plating(s) on the lead as well as microcracks within the chip or substrate.

C. Pull Test and Metallurgical Examination

It is widely accepted in the electronics industry that the pull test is a standard for wire bond quality. It is not the only measure, of course, but a bond must have a certain mechanical strength in order to survive the rigors of thermal cycling, vibration and g-force testing, and other environmental conditions which threaten the survivability of an electronic device. Thus, in many high reliability situations, a requirement is imposed upon manufacturers that 100% of the wire bonds in a device be nondestructively pull tested; that is, each wire should be subjected to a predetermined force level which is less than the anticipated ultimate fracture strength, but still high enough to stimulate weak bonds to fail. In this manner, it can be better assured that devices that pass, meet a standard of quality.

One of the important questions that remains is whether or not the nondestructive pull test weakens marginal bonds. In the case of wire bonds, the IC chip itself is mechanically attached (bonded) to a lead frame or to a substrate and the wire bonds form the electrical interconnections between various points. The wire, which may be 0.7 - 1 mil in diameter, does not perform the task of providing mechanical support for the IC chip. In the case of TAB, however, the leads are considerably larger in cross section than bond wires, and TAB leads may provide the only source of mechanical support for the IC chip for a good part of the time prior to final assembly. Good mechanical integrity of the ILBs and OLBs are essential to achieving a high probability of successful final assembly and test.

A problem facing any new method is to find a reference standard to which new results can be compared. Pull test alone is not appropriate. A true measurement of bond quality could be ascertained by metallurgical examination of leads and corresponding bond pads that are exposed after a lead is pulled off. This method is destructive, as is pull testing, however, it is not susceptible to the same artifacts and difficulties. This technique has considerable merit as a standard provided that inadvertent mechanical damage is not induced to the bonds prior to nondestructive inspection. For example, a lead may be found to have low pull strength, in agreement with low quality as determined by nondestructive SLAM, but upon metallographic examination, a larger bond area may be found to have existed at an earlier time in the sample's history. This

implies that at some time after the original bonding process, but prior to SLAM and subsequent tests, the bond had been partly damaged in handling. Therefore, in determining how good a new test is in predicting bond quality, pull test and metallographic examination should be performed so that inconsistencies in a data set, if they occur, can be resolved.

REFERENCES

1) Kessler, L.W., "Acoustic Microscopy: A Nondestructive Tool for Bond Evaluation on TAB Interconnections", Proc. 1984, ISHM Symposium.

2) Korpel, Kessler, L.W., and Palermo, P.R., "Acoustic Microscope Operating at 100 MHz", Nature, Vol. 232, No. 5306, pp. 110-111.

3) Lemons, R.A., and Quate, C.F., "Acoustic Microscope - Scanning Version", Appl. Phys. Letters, Vol 24, No. 4, pp. 163-165 (1974).

4) Product Bulletin of Sonoscan, Inc., 530 E. Green Street, Bensenville, IL, 60106.

5) Lin, Z.C., Lee, H., Wade, G., Oravecz, M.G., and Kessler, L.W., "Holographic Image Reconstruction in Scanning Laser Acoustic Microscopy", IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. UFFC-34, No.3, May, 1987, pp. 293-300.

6) Yu, B.Y., Oravecz, M.G., and Kessler, L.W., "Multimedia Holographic Image Reconstruction in a Scanning Laser Acoustic Microscope", Presented at 16th International Symposium on Acoustical Imaging, Chicago, IL, June, 1987.

7) Kessler, L.W., "VHF Ultrasonic Attenuation in Mammalian Tissue", Acoustical Society of America, Vol. 53, No. 6, 1973, pp. 1759-60.

8) Oravecz, M.G., "Quantitative Scanning Laser Acoustic Microscopy: Attenuation", Journal de Physique, Colloque C10, Supplement au n12, Tome 46, Decembre, 1985, pp. 751-754.

9) Goss, S.A., and O'Brien, W.D., Jr., "Direct Ultrasonic Velocity Measurements of Mammalian Collagen Threads", The Acoustical Society of America, Vol. 65, No. 2, 1979, pp. 507-511.

10) Oravecz, M.G., and Lees, S., "Acoustic Spectral Interferometry: A New Method for Sonic Velocity Determination", Acoustical Imaging, Vol. 13, ed. by M. Kaveh, R.K. Mueller and T.F. Greenleaf, Plenum Publishing Co., 1984, pp. 397-408.

11) Cichanski, F.J., Patent Pending.

II DESCRIPTION OF SAMPLES

There are several methods of metallurgically bonding TAB tape that are commonly employed in industry. They are gold-gold (Au-Au) thermocompression, gold-tin (Au-Sn) eutectic and lead-tin (Pb-Sn) alloys. The emphasis of this program is on the Pb-Sn type, as required by the contract and these were obtained from GTE Communications Systems in Northlake, IL, who provided the tape and bonding, with the cooperation of Delco Electronics, Kokomo, IN, who provided the bumped chips. Throughout this report these samples are referred to as the "solder" samples. The techniques for nondestructive inspection of TAB bonds developed in this study should also be useful for other, more popular types of bonding than the Pb-Sn. Therefore, for illustration purposes, a few samples of Au-Au thermocompression ILBs and of Au-Sn eutectic ILBs were obtained from MESA Technology in Mountain View, CA. These are referred to as the "MESA" samples in this report.

In order to develop a test method for bond quality, it is desirable to have available, samples which exhibit a range of characteristics from good to bad as defined by some standard. Therefore, the solder samples were manufactured with a wide range of quality by purposely altering the bonding parameters i.e., temperature, thermode pressure, and dwell time. Each parameter was deviated from the norm in a positive and negative direction, thereby creating a 3x3x3 matrix of possibilities. Not all of the samples survived because of the extreme fragility of the worst ones, but a sufficiently wide range of quality samples was available for use in this study. Figure 2-1 illustrates the matrix of variables and the sample identification numbers for the solder ILBs; Fig. 2-2 illustrates the same for the solder OLBs. Figure 2-3 is a photograph of the test chip with the inner lead bond wires attached. Figure 2-4 is a photograph of the test chip after it has been outer lead bonded to a 2"x2" alumina substrate. The specifications of the bond sites are listed below in Tables 2.1 and 2.2 for the "solder" bonded samples and for the "MESA" samples.

TABLE 2.1: SPECIFICATIONS OF THE "SOLDER" BONDED SAMPLES

Inner Lead Bond Sites:
- Test chip: GTE Drawing 49-D-4394-8
- Chip size: 225 mils square
- Pad layout: 126 pads arranged in 2 rows. 63 pads bonded
  4 mil square pads on 10 mil pitch (nominal)
- Bump configuration: 1.5 mil solder over 1.2 mil silver bump
- Solder: 90% Pb, 10% Sn reflowed
- Number of samples included in study: 29

Outer Lead Bond Sites:
- Substrate: 2" x 2" alumina ceramic
- Bond pads: thick film Palladium Silver with
  60/40 PbSn solder reflowed
- Pad Layout: 10 mil x 20 mil pads on 20 mil pitch (nominal)
- Number of samples included in study: 24

Tape Configuration:
- 3 layer Kapton tape with 1 mil Tin plated Copper
- 35 mm standard sprocket holes
- Cu tape width at inner lead: 3.6 mils
- Cu tape width at outer lead: 10 mils

Chip bumping supplied by Delco Electronics, Kokomo, IN.
Chip design, bonding operations and substrates supplied by GTE Communication Systems, Northlake, IL.

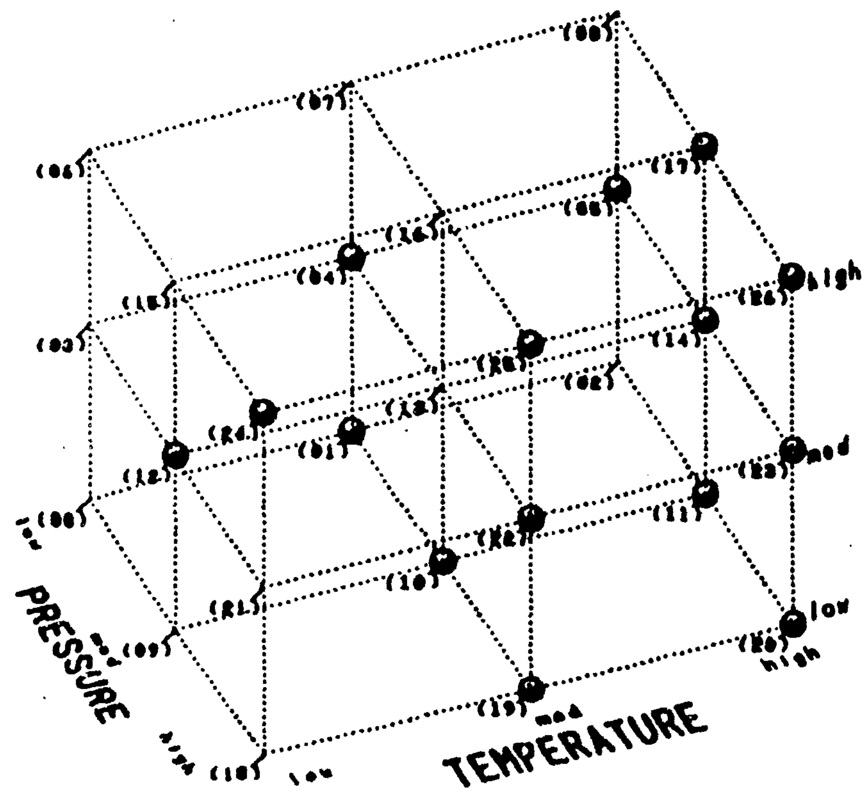
TABLE 2.2: SPECIFICATIONS OF THE "MESA" SAMPLES:

Inner Lead Bond Sites:
- Test chip size: 250 mil square
- Pad layout: 68 I/Os, 4 mil pads on 10 mil pitch
- Bump configuration: straight wall, 1 mil high, Gold
- Number of samples included in study: 2
- Tape configuration: 3 layer Kapton tape with 1.4 mil Gold Plated Copper
- Cu tape width at inner bond: 3 mils

Au-Sn Eutectic ILBs:
- Test chip size: 250 mil square
- Pad layout: 68 I/Os 4 mil pads on 10 mil pitch
- Bump configuration: straight wall, 1 mil high, Gold
- Number of samples included in study: 2
- Tape configuration: 3 layer Kapton tape with 1.4 mil Tin Plated Copper
- Cu tape width at inner bond: 3 mils

Complete chip assemblies supplied by Mesa Technology, Mountain View, CA.

POS	PRES	TIME	TEMP	SAMPLES INCLUDED
00	L	L	L	none
01	L	L	M	59-2 59-3 59-4 61-5
02	L	L	H	none
03	L	M	L	none
04	L	M	M	60-2
05	L	M	H	57-4
06	L	H	L	none
07	L	H	M	none
08	L	H	H	none
09	M	L	L	none
10	M	L	M	62-5
11	M	L	H	53-2 63-5
12	M	M	L	42-4 42-5
13	M	M	M	none
14	M	M	H	54-4
15	M	H	L	none
16	M	H	M	none
17	M	H	H	55-5
18	H	L	L	none
19	H	L	M	47-5
20	H	L	H	50-2 50-4 50-5
21	H	M	L	none
22	H	M	M	48-3 48-4 48-5
23	H	M	H	51-3 51-4 51-5
24	H	H	L	46-4
25	H	H	M	49-4 49-5
26	H	H	H	52-3 52-4 52-5

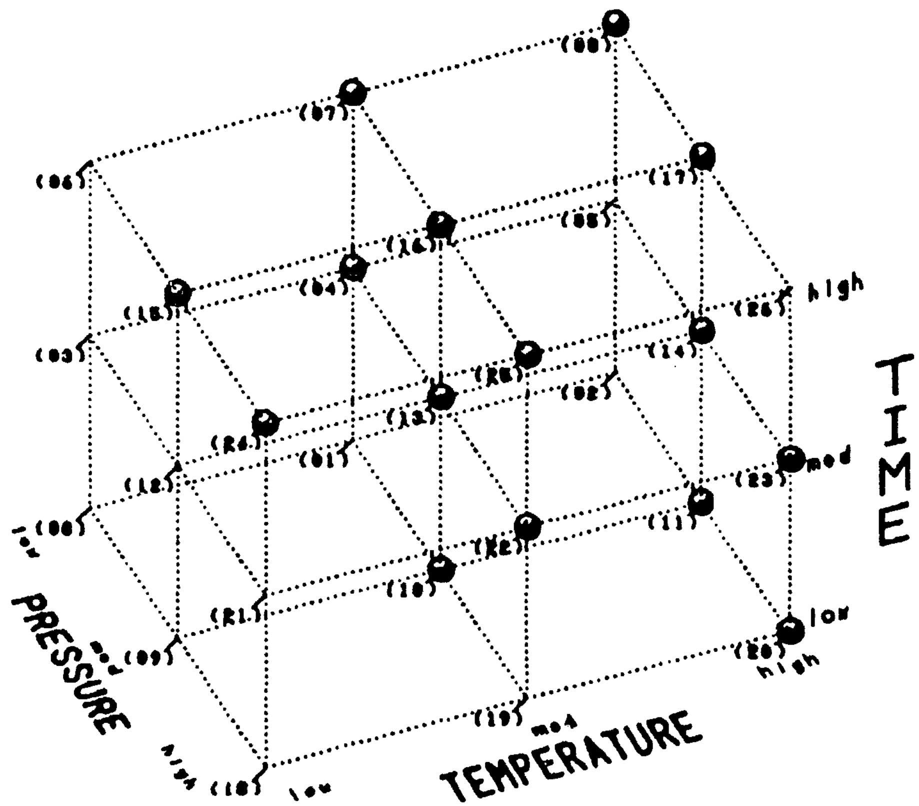


NOMINAL VALUES

	Pres	Time	Temp
high	7	5.9	390
med	3	4.9	340
low	1	3.9	280

Figure 2.1. Description of Solder ILB matrix of samples.

POS	PRES	TIME	TEMP	SAMPLES INCLUDED		
00	L	L	L	none		
01	L	L	M	none		
02	L	L	H	none		
03	L	M	L	none		
04	L	M	M		17-8	
05	L	M	H	none		
06	L	H	L	none		
07	L	H	M	16-2		
08	L	H	H	21-2	21-8	
09	M	L	L	none		
10	M	L	M		39-4	
11	M	L	H	37-2	37-4	
12	M	M	L	none		
13	M	M	M	30-2	38-5	
14	M	M	H	36-2	36-4	
15	M	H	L		24-6	
16	M	H	M	20-2	28-4	
17	M	H	H	35-2	35-4	38-6
18	H	L	L	none		
19	H	L	M	none		
20	H	L	H	34-2	34-8	
21	H	M	L	none		
22	H	M	M	31-2		
23	H	M	H	33-2	08-6	
24	H	H	L		25-5	
25	H	H	M	29-2	29-5	
26	H	H	H	none		



NOMINAL VALUES

	Pres	Time	Temp
high	22	3.0	320
med	11	1.5	290
low	5	0.0	260

Figure 2.2. Description of Solder OLB matrix of samples.

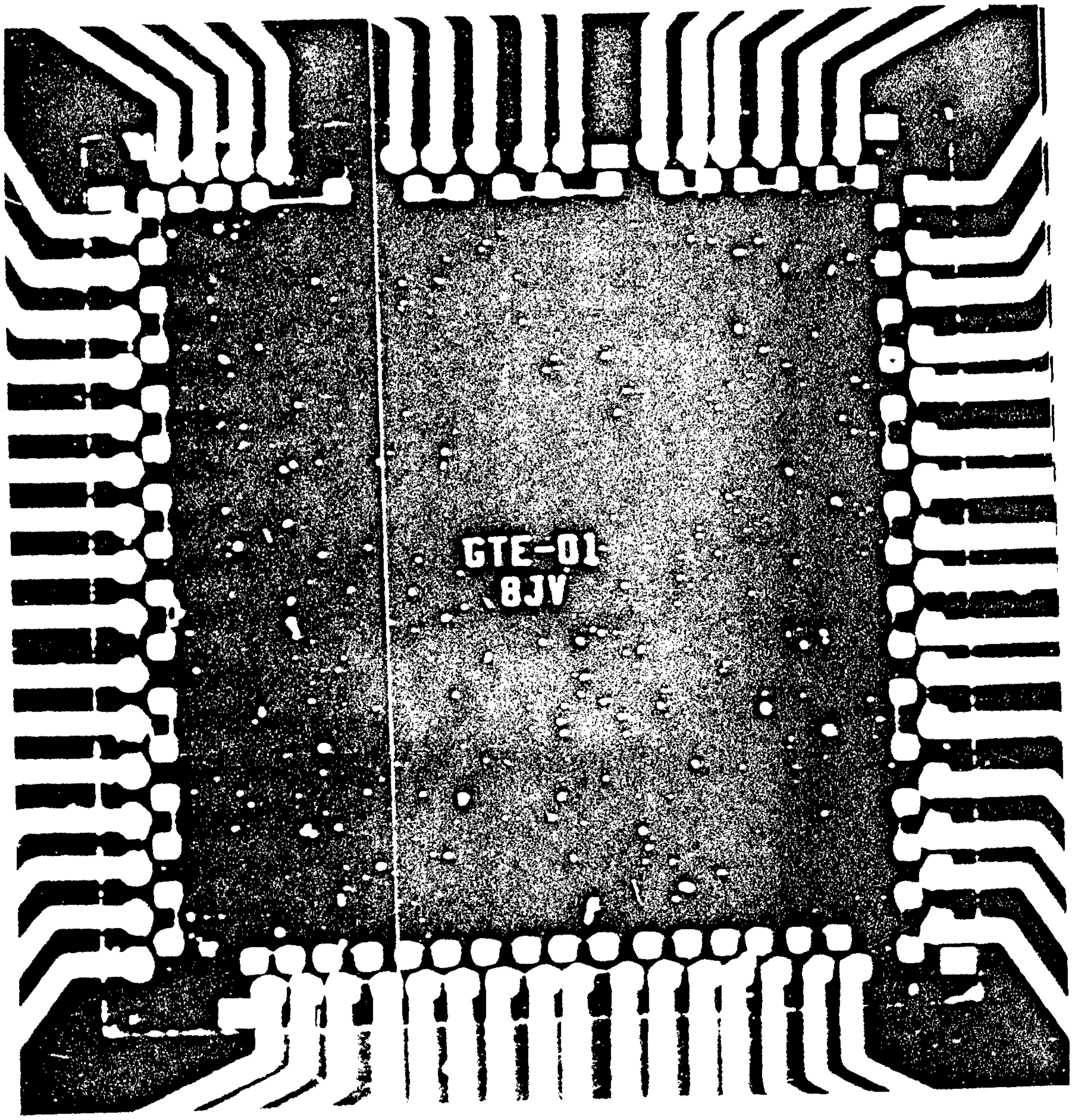


Figure 2.3. Photograph of inner lead bonded test chip.

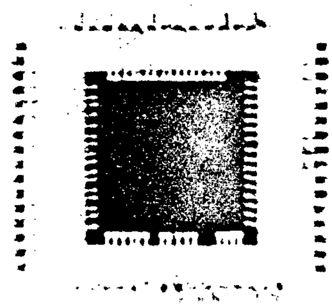


Figure 2.4. Photograph of test chip outer lead bonded to Alumina substrate.

In order to prepare for systematic examination of the samples, a series of trial runs was performed on the SLAM in order to work out sample handling problems. With regards to the OLBs the 2" x 2" ceramic substitutes served as sample holders and allowed easy manipulation and positioning of the bonds under the field-of-view. With regards to the ILBs however, it was found to be more convenient if the long strips of 35mm film were cut into individual pieces, each consisting of one die and the asociated TAB lead frame. Acoustic examination could be performed on the strips as well, however, a special fixture would have to be constructed. The individual strips worked best when they could be kept flat against the stage surface; they had a tendancy to curl. Flexing of the TAB tape can cause unwanted stresses on the ILBs and possible damage. To solve this problem, the ILB samples were placed into 35mm slide carriers manufactured by CAMTEX Horizons, Inc., Fremont, CA. A diagram of this holder is shown in Fig. 2-5 and a photograph of an assembled unit with chip is shown in Fig. 2-6.

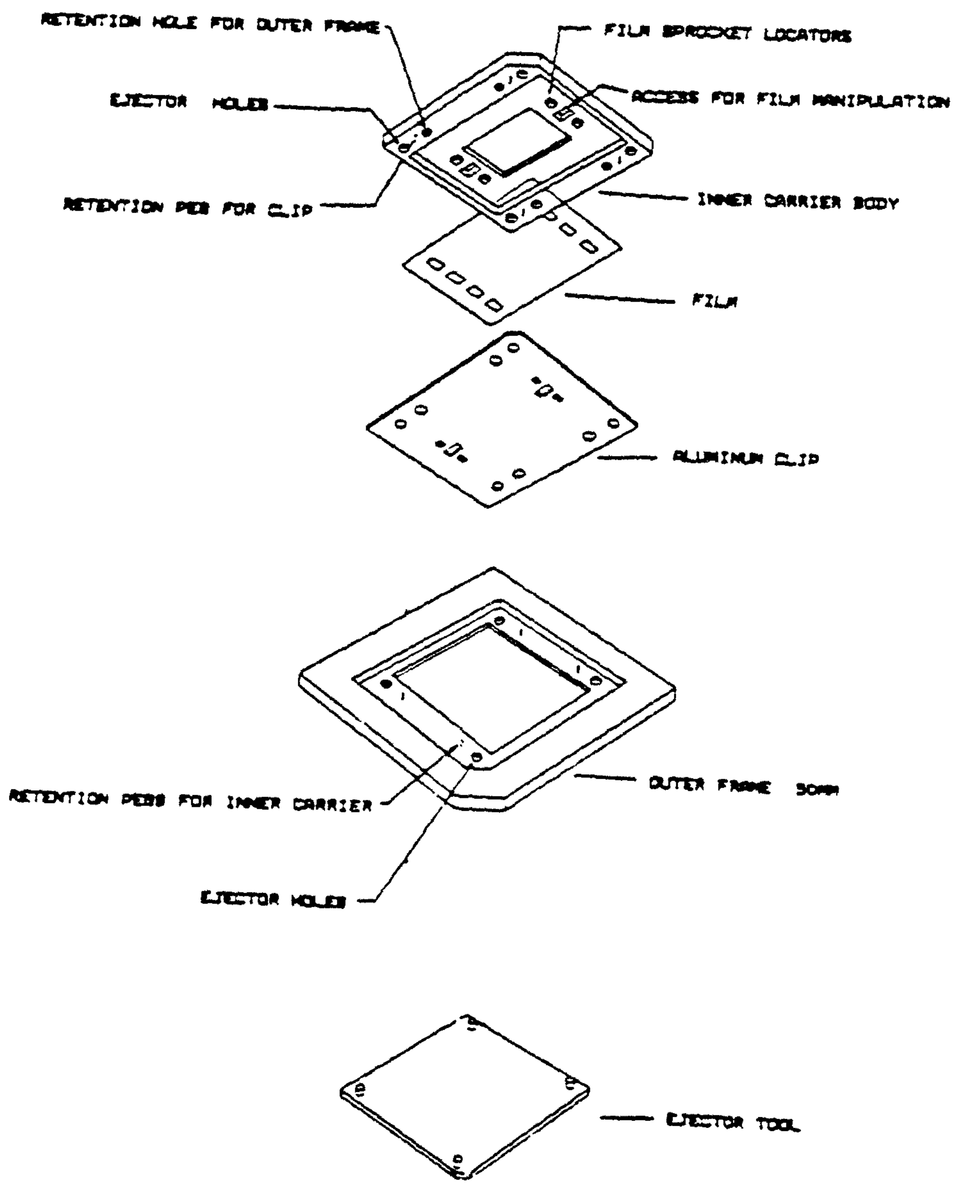


Figure 2.5. Diagram of 35mm slide carrier manufactured by Camtex Horizons, Inc.

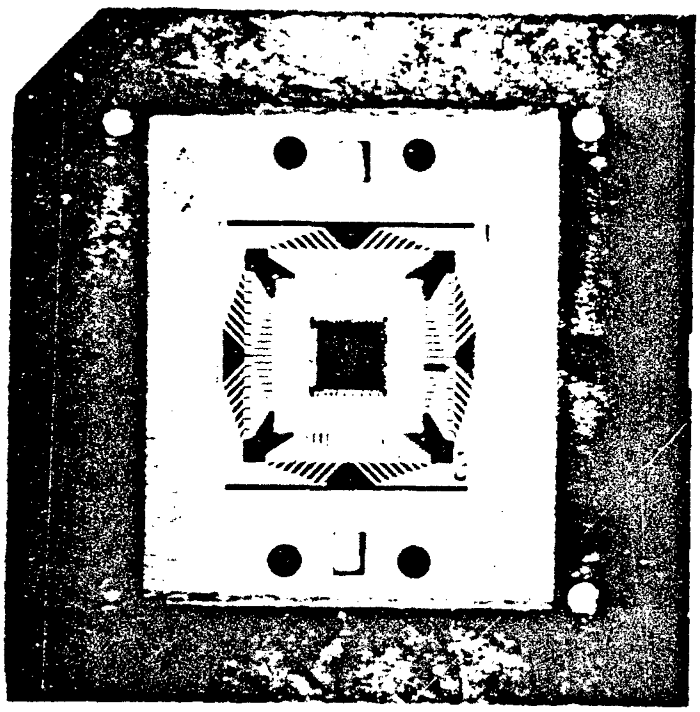


Figure 2.6. Photograph of ILB sample assembled into slide carrier.

III. EXPERIMENTAL METHODS AND EQUIPMENT

A. SLAM

1) Basic Operation

The SLAM employed in this study to inspect the OLBs was a standard commercially available instrument operating at a frequency of 100 MHz. Early images of the ILBs were also produced at 100 MHz. However, because of their smaller sizes, it was felt that better resolution would be desirable at a higher operating frequency. A frequency of 200 MHz was empirically chosen for the ILBs based upon an optimization of signal-to-noise ratio and resolution. Frequencies beyond 200 MHz did not have as good penetration through the sample and the speed of scan would have become restricted to compensate. At 200 MHz real-time operation of the SLAM was maintained and the resolution was improved to about 11 microns size. The instrumentation was suitably modified to achieve this new capability and the improvements made were incorporated into the list of standard available options for commercial SLAM systems.

From an operational perspective, the SLAM operation can be explained according to the block diagram shown in Fig. 3-1. The sample is illuminated with a collimated beam of ultrasound (insonification) which is located within the microscope stage. Since this ultrasound will not travel through air, a coupling fluid, such as high purity methanol or distilled deionized water is placed upon the stage to couple the energy to the sample. In the manual mode the sample is free to move upon the stage in the x-y direction so that different areas can be rapidly screened by an operator, or inspected in detail. An automatic sample positioner was also developed to systematically tour the sample through the field-of-view; this is described later.

Since the TAB tape is not optically smooth and reflective, a coverslip mirror is placed in close proximity to, but not in mechanical contact with the sample's top surface. This small space is filled with fluid couplant and the ultrasound information on the bond is projected onto the lower surface of coverslip where it is imaged by the scanning laser beam. The basic theory of SLAM operation was covered in section I B and has been discussed extensively in the literature.

Referring back to the block diagram, Fig. 3.1, the light beam reflected from the microscope stage carries two channels of information about the sample; the acoustic image which shows internal bond layers and an optical reflection image of the sample surface. This optical image is a valuable aid to the operator when an anomalous area is located acoustically since it provides immediate visual information feedback about possible artifacts, missing leads, misalignments, and visible damage to the sample. The acoustic and visual images are precisely aligned with one another since the same laser beam scan produces the data. The images are viewed on separate CRTs located above the control panel next to the stage. A photograph of the SLAM system is shown in Fig. 3.2 for reference. The modifications for 200 MHz operation are not obvious in the external appearance of the instrument since they are primarily electronic in nature.

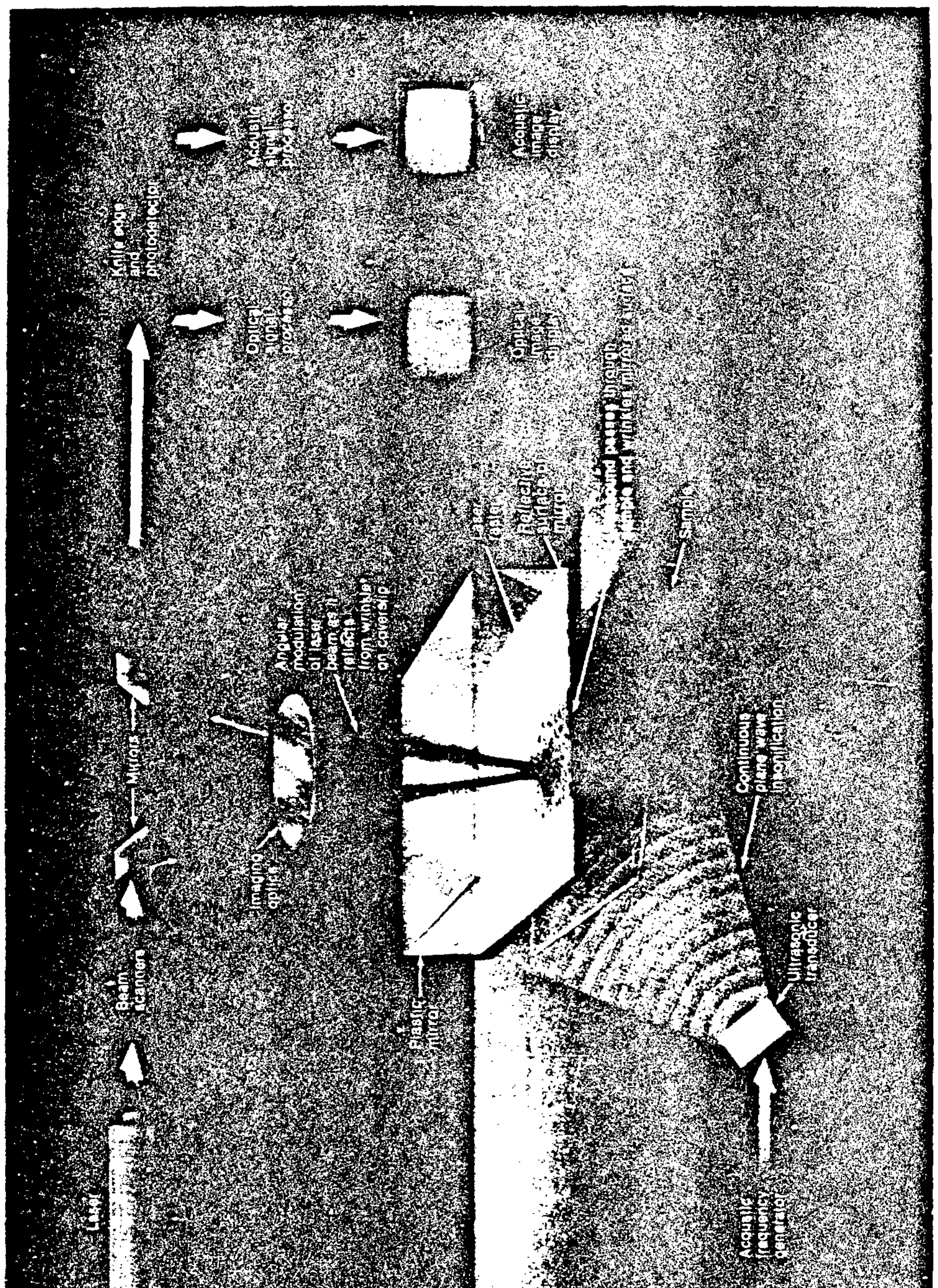


Figure 3.1. Block diagram of SLAM operation.

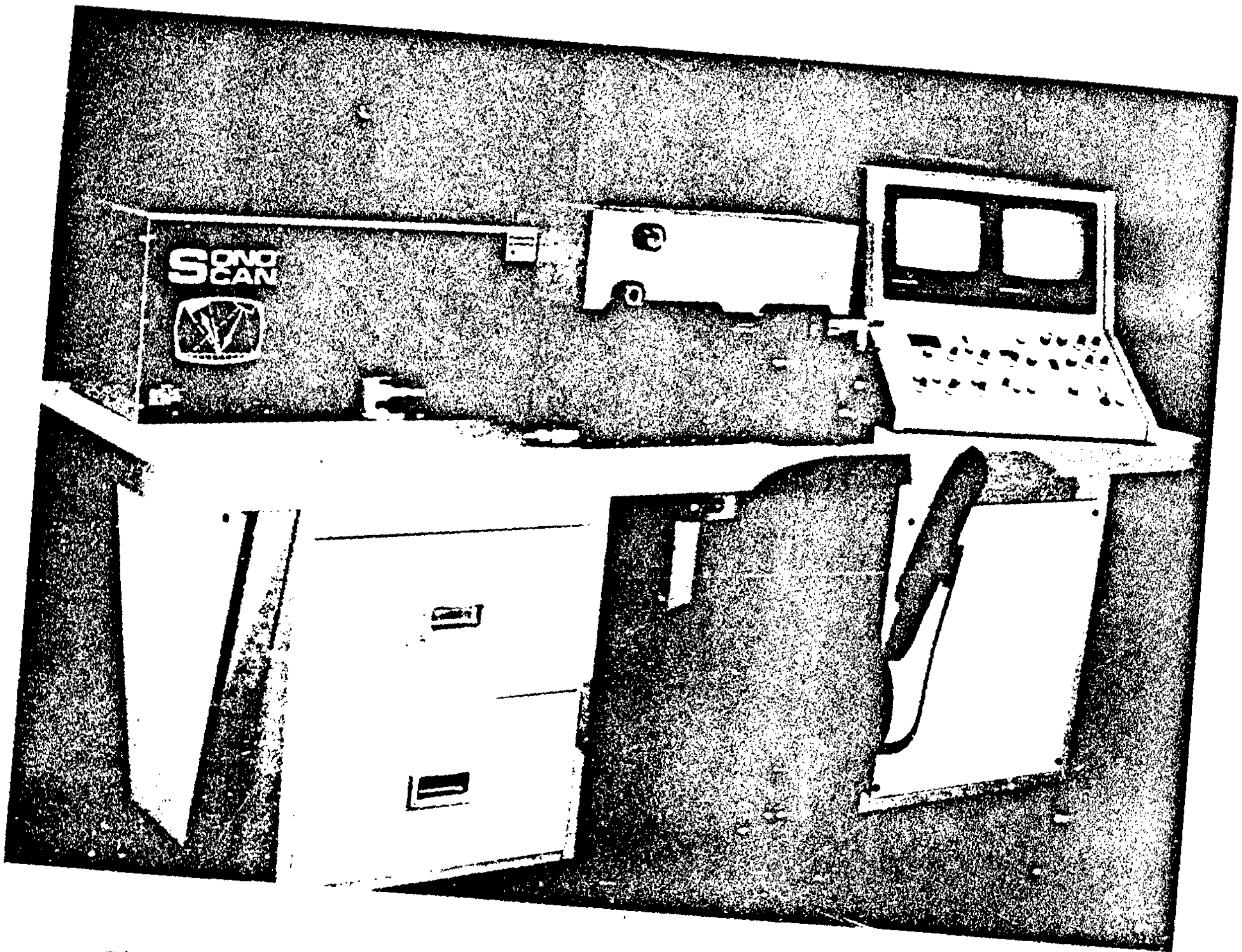


Figure 3.2. Photograph of typical SLAM system.

2) Automatic Positioning of Sample

In the course of inspection of TAB devices by SLAM there is needed a means to accurately position and scan certain or all areas of the sample. Especially at high frequency (high resolution and high magnification), the task of placing and indexing the sample involves considerable operator involvement and time. Therefore, an automated indexer has been developed to minimize this overhead, while simultaneously eliminating the possibility of operator errors and omissions. The indexer is specifically coordinated to the needs of SLAM, and is modular to allow its broadest possible application. The controlling software allows the "training" of the indexer to cover all variations of desired index repertoires. Additional program-controlled outputs are available to perform external functions, such as the switching of recorders, feeders, and other apparatus.

Indexers for sample placement in many environments abound in the current market. However, SLAM requirements are different than encountered in many other applications. Samples by necessity must be submerged in coupling fluid. There

is often a certain required angle of insonification, which determines a tilted plane within which sample placement occurs. A coverslip is usually required, and it not only must be placed very close to the sample, but must be capable of being slightly tilted around two axes for correct alignment, and also translated along a third axis for optical focus under the scanning laser, maintaining this intimate proximity to the sample. Altogether, there are six degrees of motion which must be adjusted in the use of SLAM, once the angle of insonification has been fixed. With reference to Figure 3.3, these are:

1) Coverslip/Sample clearance
2) Coverslip tilt around x-axis
3) Coverslip Tilt around y-axis
4) Coverslip laser focal position, along z-axis
5) Sample x'-axis position
6) Sample y'-axis position

Of these, the first four are basically a "once per set up" adjustment. There is no special need for their automation, and indeed, they depend to a large degree on operator observation and feedback, which are not so readily automated. However, sample positioning itself, once the overall machine settings are established, is highly desirous of automation. The performance of this without limiting or upsetting the other adjustments is the accomplishment of the present indexer as shown in the diagram Fig. 3.4.

The complete indexer unit contains:

A) Mechanical Assembly
   1) Basin Unit containing angled floor, ultrasound transducer, and unitary-aligned drive platform.
   2) Dual crossed linear slides, mounted upon drive platform, and powered by micro-positioning linear actuators.
   3) Interchangeable sample-holding fixtures mounted upon top of slide assembly.
   4) Coverslip gantry mounted upon Basin Unit, allowing adjustment of Coverslip/Sample clearance, and allowing coverslip to be flipped away for optical inspection of the sample.
   5) Support yoke fixture and base, allowing focal elevation adjustment, and two degrees of angular adjustment for overall coverslip alignment.

B) Servo Controller Unit
   1) Motor power supplies
   2) Motor output servo driver amplifiers
   3) "Macro-language" command Interpreter
   4) Two-way communications with host computer

C) Host Computer
   1) PC-Compatible MS-DOS system as system orchestrator
   2) CRT Monitor and standard Keyboard for Operator Interface
   3) Disk Storage of Index Repertoires
   4) Two-Way Communications with Servo Controller

D) Software
   1) General Operating Program
   2) Repertoire-building ("training") Software
   3) Position and State Display
   4) Direct "Joystick" operation using Arrow Keys
   5) Automatic and Semi-Automatic operation with Operator Prompts
   6) User-developed Libraries of Indexing Repertoires

The basic standard design of the Basin Unit has a floor angle (angle of insonification of coverslip) of 10 degrees, a nominal 2 x 2" sample size, and the ability to accomplish an approximate 2 x 2" sample travel along the x'- and y'-axes (sample travel axes tilted 10 degrees with respect to the plane of the coverslip). However, variants of these specifications are possible, and special adaptations are relatively easy to perform. The dual crossed linear slides and the micro-positioning linear actuators in the standard design are 1-inch travel (approximate) members of families containing a number of other sizes. The linear actuators are servo motors, and respond to position encoders of an effective "step size" of 1.782 microns (70.16 micro inches), thus theoretically allowing positioning to this precision.

The sample holder fixtures are made to suit the specific slide carriers. In many cases, the fixtures must be very thin (on the order of a few tens of mils), in order to assure the minimum coverslip/sample clearance. The fixtures are applied over alignment pins on the slide assembly, and held in place with two screws. They are rapidly interchangeable.

The coverslip gantry consists of a bridge over the basin, and a coverslip holder slide-mounted with teflon bearings on two precision-ground stainless steel dowels. Coverslip/sample clearance is set with a single thumb screw. The coverslip pivots from its in-use position to allow optical inspection of the sample. The pivoting can be performed by hand, or can be arranged for solenoid-activation.

The support yoke fixture and base contain the apparatus necessary to make the elevation and the two tilt adjustments necessary for the correct focal position and coverslip angulation. Elevation is adjusted by a broad thumb wheel near the base, which causes a height change of approximately 0.0002" per degree. The tilt adjustments are manual knobs giving approximately one degree of tilt adjustment per turn.

The servo controller has self-contained power supplies for itself, and for the linear actuators. It acts as a complete servo system for the two axes (x' and y') of sample motion. It receives motion commands, and commands to change motional parameters from the host computer, and returns position and other status information to the computer. These communications occur in a type of "macro" language, which the host computer's program has been taught to speak. Communication typically occurs over an RS-232 connection, with a baud rate of 9600.

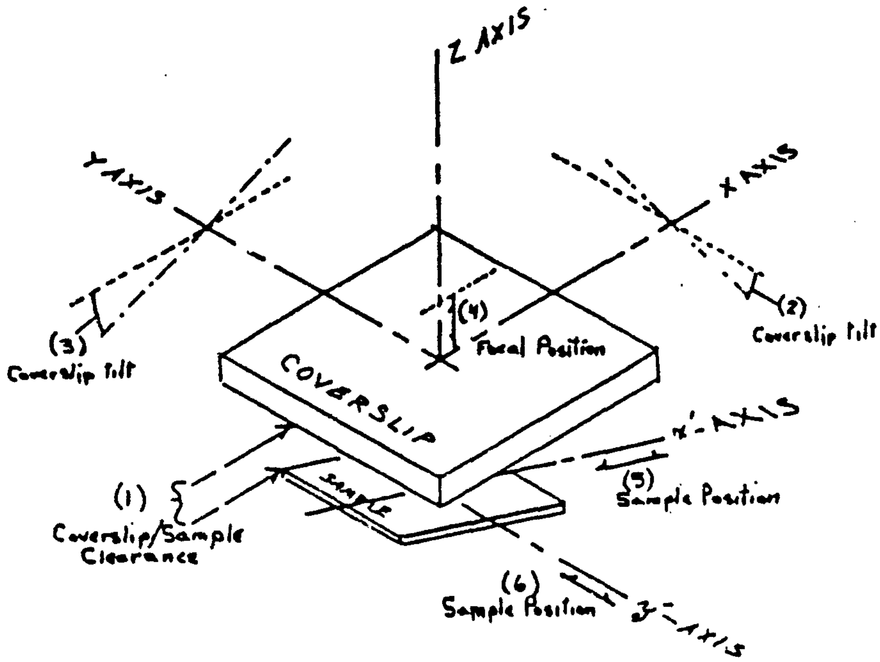


Figure 3.3 Diagram of alignment geometry.

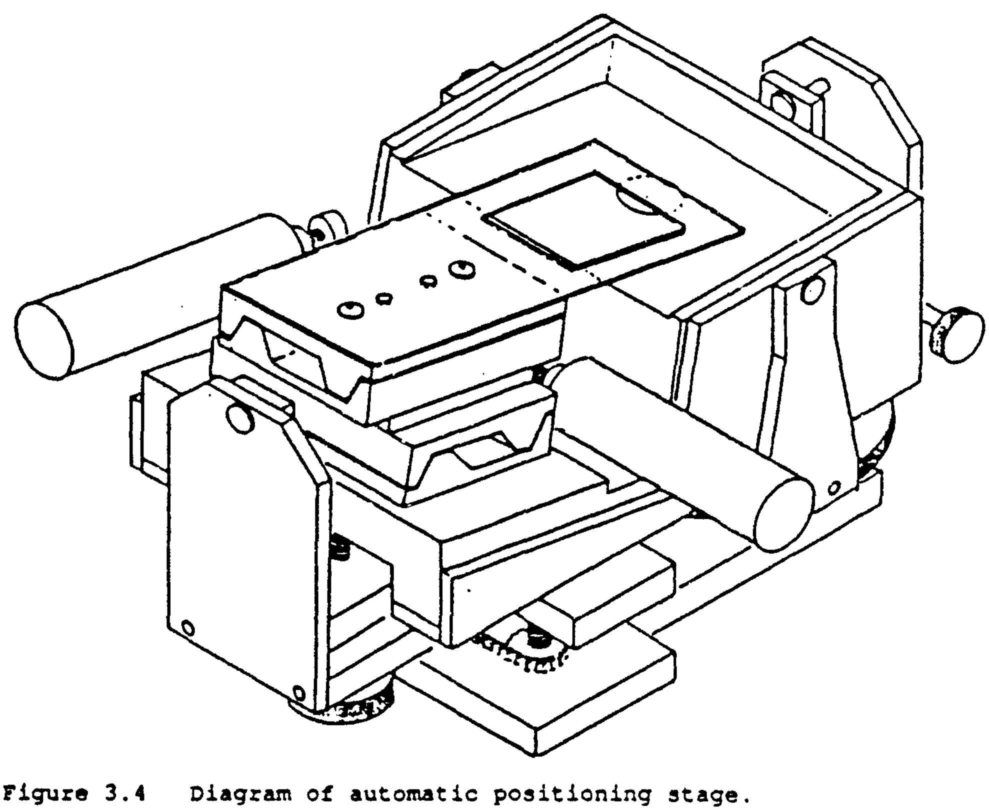


Figure 3.4 Diagram of automatic positioning stage.

When a sample is to be viewed, the appropriate sample holder fixture is put in place, and the sample inserted. The operator then selects the correct index repertoire from the software library, and indexes the machine to a known home position. These are done by pressing the appropriate function keys, as directed by the menu. The joy-stick functions are called by using the four arrow keys on the numeric keypad, in order to compensate for any irregularity in internal sample position, and this new point is made the home position. By pressing the appropriate function key, either automatic, or semi-automatic operation is begun. If no index repertoire exists for a new piece, the operator simply selects the appropriate key, and is led through a "training session", wherein the joystick is used to visit the various positions which are remembered by the host computer. By pressing the appropriate key, a VCR "snapshot" is taken of a desired section of the sample, or a VCR can be left to free-run during sample touring.

3) Digital Image Analyzer (DIA)

The SLAM Digital Image Analyzer consists of several image analysis programs of various capabilities. For the purposes of determining area fractions, the following proceedure is used:

A SLAM acoustic or SLAM optical image is presented to the video memory (called up from disk or other storage as needed), and is viewed by the operator. An analysis window of the desired size and shape to represent 100% bond area is placed on screen and moved to the appropriate position. A threshold is established reprsenting the optical density which discriminates bonded from unbonded regions. The area within the window becomes a two-valued image, either black or white, for operator confirmation that the threshold represents the bond area. The software then calculates the area fraction based upon pixel occupancy.

The analysis window then is moved to each successive bond site, and the calculation for each site is performed and recorded.

The establishment of the threshold optical density level was dictated by the apparent transition from light to dark regions within the bond area. Fortunately, this transistion is fairly abrupt, allowing threshold to be selected with little ambiguity.

The initial establishment of the desired size and shape of the analysis window is dictated by the potential maximum size of the bond (with reference to Fig. 3.5). The maximum bond width is the width of the beam lead at the bond site. In all cases in this study, the bond pads were wider than the leads, thereby assuring the potential of full coverage. The bond length is determined by the geometry of the thermode, which causes a certain length of the beam lead to become bonded. From acoustical and optical images of the inner and outer lead bonds, the values of these dimensions were determined, and used to generate the respective windows. These windows thus became the product of the respective widths and lengths, and bond area fraction was measured relative to them.

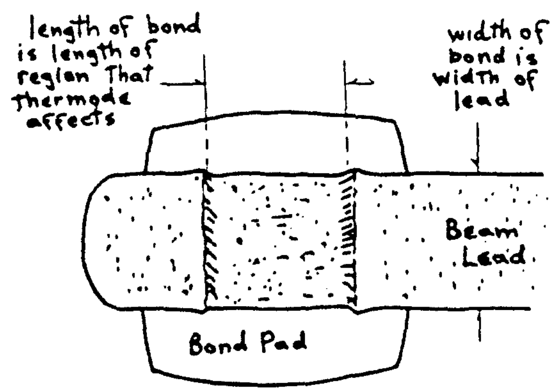


Figure 3.5. Illustration showing definition of maximum bonded area.

4) Specific Operator Methodology

The inspection of samples and acquisition of SLAM data is preceeded by instrument setup and calibration. As previously discussed, in the SLAM the acoustic data are obtained by means of a scanning laser beam. Therefore, the optical performance of the system is the first step in calibration. A test sample is used to verify laser focus at the sample plane and to calibrate the field-of-view, or magnification. A standard USAF test target made on glass is used to verify spatial resolution of the system.

The acoustic mode can be used after verification of optical performance specifications. The acoustic frequency range of choice is selected and the coupling fluid placed upon the stage. With no sample in place a bright uniform image is obtained and the equipment sensitivity is measured by means of an electrical attenuation reference standard. A uniformly illuminated (with sound) area is chosen and a sample of interest is introduced. The coverslip is carefully positioned in height to permit the sample to be easily indexed throughout the field of view without mechanical contact by the coverslip. In order to minimize imaging artifacts such as speckle and reverberations which are characteristic of coherent monochromatic insonification, the frequency modulation mode of the SLAM system is employed. Images thus obtained are essentially made with incoherent acoustic wave illumination. Each sample is systematically positioned through the field-of-view of the SLAM and images are recorded on computer disc for subsequent analysis and archival purposes. From these images quantitative data are obtained on the acoustic wave transmission level through the bond sites and data are obtained on the area of each lead that is bonded.

B. Pull Test Methodology

1) Hook Pull Test Method at Sonoscan

The pull test unit employed was a TERRA UNIVERSAL model as shown in the of experimental set-up, Fig. 3.6. The gage of appropriate range was outfitted to the pull tester. In general, most samples needed a gage of nominal range of 5-50 grams. Upon encountering a sample that displayed very low strengths a gage of the nominal range 2-15 grams was employed in order to maintain optimum readability and resolution. Upon encountering a sample having higher strengths, a gage of the range 20-150 grams was employed. Samples were mounted on a chuck under a 10x stereoscopic microscope.

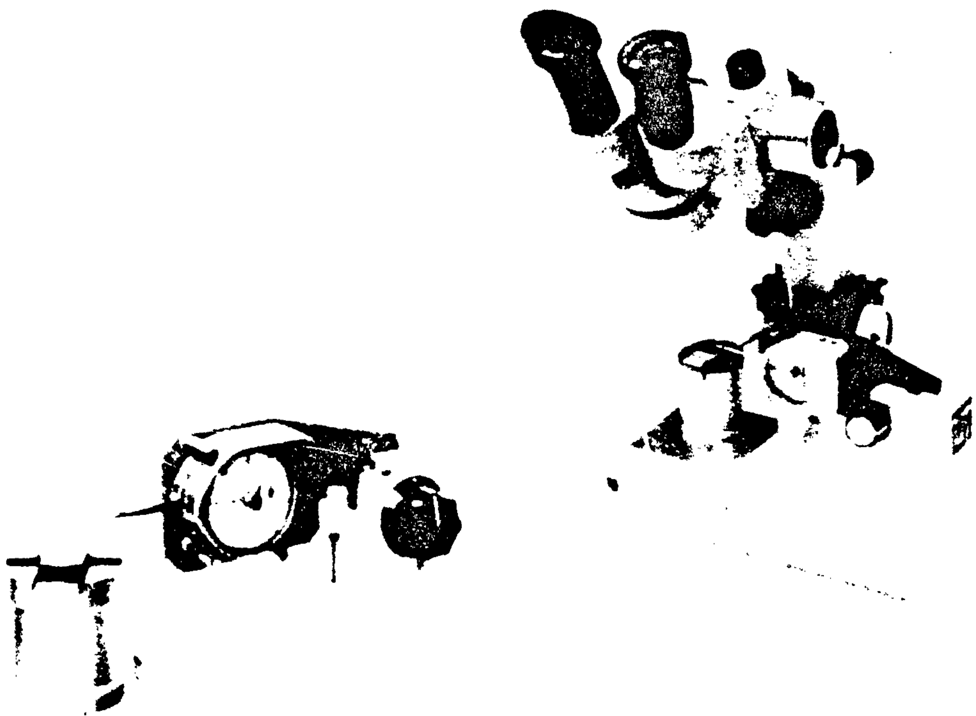


Figure 3.6. Photograph of Hook Pull test apparatus.

a) ILB Preparation and Test Procedure

Each individual ILB TAB sample consisted of a section of polyimide tape supporting the outer lengths of the beam lead array, the beam lead array itself,

and a semiconductor die suspended by the inner ends of the beam lead array by gang-bonded inner lead bonds (ILB) at sixty three positions. A sixty fourth position (that numbered as position ten) was without bond or lead.

In the preparation procedure, the backside (without bonds) of the semiconductor die was first secured to a glass slide by the use of a measured portion of rapidly curing cyano methyl acrylate cement. A minimum amount of pressure was then applied, along the outermost edges of the polyimide tape, to frictionally restrict any motion of the tape with respect to the glass slide (which motion would be capable of communicating stresses to the bonds at the now-immobile die) so that the polyimide could be anchored to the glass slide as well. The anchoring was then performed by application of ordinary cellophane adhesive tape at the sprocketed edges of the polyimide tape. Thus, at the die, each beam lead was secured solely by its inner lead bond. At the opposite end, the beam was secured by its conjunction with the polyimide lead frame support tape, the overall strength of which was radically higher than the anticipated yield strength of the bond, thereby eliminating the jeopardy of yielding occurring at the outer end of the beam lead. With these terminal bodies of the beam leads secured, the pull test was commenced.

The sample was aligned with the hook, placing the hook under bond position number one. The hook was positioned under the beam lead as close to the semiconductor die as possible. During this act of positioning, a stop is engaged to prevent the application of force by the pull tester. After this positioning the stop was released, and the pull tester produced force at a rate moderated by dash-pot control. The lead was subjected to this increased force until the moment of failure, whereupon the peak force recorded by the gage was transcribed to the laboratory notebook. The alignment and the pull test procedure was then performed on the remaining leads, in sequential order.

It is observed that despite the positioning of the hook close to the die, some amount of displacement occurs by sliding of the hook along the beam lead. This is most pronounced where the length, especially slack length, of the lead appears to be maximum, at and near the corner of the die. An amount of twisting and buckling of the lead is seen to occur as the staggered ("dog-legged") geometry is deformed by the pull.

b) OLB Preparation and Test Procedure

Each individual OLB TAB sample consisted of a substrate upon which was mounted a semiconductor die, and beam lead array supported at both ends of each lead by a bond. The inner lead bonds were much the same as those in the samples formally committed for inner lead bond testing. However, there were also present outer lead bonds, and these were to be the subject of the test.

In order that the inner lead bonds not give way during the test, it was necessary that the leads be anchored at the ILB site by additional means. To this purpose, they were cemented to the top of the semiconductor die by means of a fast-cure ("five-minute") type of epoxy resin. This material was introduced while in its mobile phase to the center of the semiconductor die, and persuaded by a massaging motion (avoiding the inner lead bond areas) to spread to the ILBs and engulf them, without further proceeding past the edge of the semiconductor

die. The epoxy was allowed to fully cure for a time of several hours prior to performing the pull test.

The sample was aligned with the hook, placing the hook under bond position number one. The hook was positioned under the beam lead as close to the outer lead bond as possible. During this act of positioning, a stop is engaged to prevent the application of force by the pull tester. After this positioning the stop was released, and the pull tester produced force at a rate moderated by dash-pot control. The lead was subjected to this increased force until the moment of failure, whereupon the peak force was recorded by the gage and was transcribed to the laboratory note book. The alignment and the pull test procedure was then performed on the remaining leads, in sequential order.

In the cases of a few samples, it was found that the semiconductor die was not attached to the substrate. In these cases the die was manually held in place during the test.

2) Tweezer Pull Test Method at GTE

Included in GTE's returned data were literature descriptions of a DAGE series 22 microtester, an MCT20 LC1 pull cartridge, an MCT20 LT1 load tool, and an MCT20 LC12 tweezer pull cartridge accompanied by the following missive:

a) OLB Test Procedure

"The substrate with the bonded chip is placed under a microscope. Using a sharp edged instrument such as a single edged razor blade, the beams were cut by placing the edge of the blade on the beams just forward of the bonds on the chip and rocking the knife back and forth until the beams were cut through. Repeat this proceedure for the remaining three sides. Carefully remove the chip from between the severed beams."

"Place the alumina substrate with the bonded beams into the pull tester. Select the beam to be tested and carefully bend the beam up 90 degrees. Open the chuck of the pull tester and align the beam and the open chuck. Lower the chuck so the beam will be between the jaws when the chuck is closed. Initiate the test cycle and close the chuck. The pull tester will record pull strength when failure occurs. Repeat the pull procedure for the remaining beams."

b) ILB Test Procedure

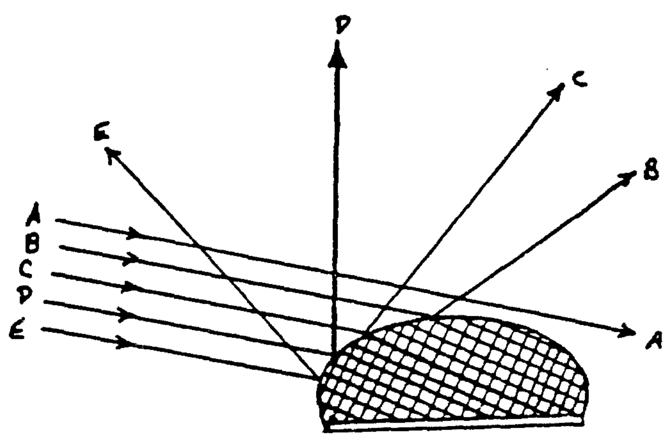
"For the ILB pull testing the beam and chip assembly must first be separated from the carrier. The proceedure used was to cut the beams from the carrier with a sharp scissor using the inside edge of the carrier as a guide. As each side is cut, carefully rotate the chip so the next side can be cut. Once the carrier has been trimmed away, the chip with the beams attached is epoxied to an alumina substrate, taking care not to get epoxy on the beams. In a similar manner as used for the OLBs, the beam to be pull tested should be formed at 90 degrees to the substrate. Use the same alignment proceedure and cycle initiation procedure as described in the OLB pull test procedure."

3) Hook Pull Test Method at MESA

MESA employed the same pull test equipment as used at GTE (Dage series 22); however, in pulling their inner lead bonds, they used hook rather than tweezer pull. Also different in the procedure was the existence of an additional band of polyimide positioned close to the sites of the inner lead bonds. This band may have acted to decouple the short region of beam lead near the actual ILB site from the dog-legged section of the lead. This factor will be seen to be important in further analysis.

C. Metallographic Examination

Optical metallographic evaluation after destructive pull testing is done in an attempt to determine, as closely as possible, the real area that each bond had occupied. Being optical in nature, this method depends upon differences in reflectivity of the bond pad area between regions with different bonding histories. When lit from an appropriate angle, the bond pad areas will appear dark at most places, due to their smooth nature. Light is only reflected to the observer from those regions having the correct angle. As the majority of the bond pad reflects the light, in a specular fashion, away from the observer, the bond pad appears generally dark. Those regions which have a textured surface will scatter the light so that an appreciable amount reaches the observer, causing the textured area to appear brighter. In Figure 3.7, rays A,B,C,D, and E impinge upon the sample, shown in cross section. Of these, only ray D strikes the sample at that angle appropriate for reflection to the observer. Thus, a thin band at the edge of the sample is seen as bright; the rest of the sample remains dark.



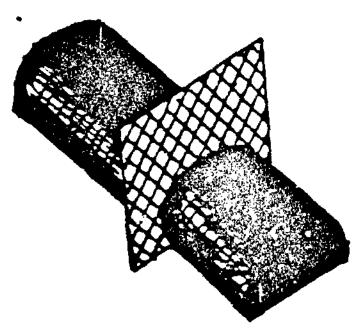


Figure 3.7. Illustration of optical ray paths for inspection of bump after pull test.

When performing optical metallographic examination, the following symptoms are anticipated:

1) In the case of no bonding, and no contact, such as the case of position number ten, the original bond pad on the OLB substrate is seen, usually with no effect from the thermode except as may have been caused by incidental contact.

2) In the case of poor bonding due, perhaps, to an insufficiency of heat or pressure during the bonding process, an imprint is seen having a generally smooth surface (little texture), caused merely by contact pressure. Such a bond might remain intact in the face of little or no disturbance by virtue of the clinging of the two surfaces that have been pressed into conformity, but such a bond is extremely weak, and is not really, within the scope of the present intent, a bond at all. Due to the change in the surface contour caused by the deformation of the surface in this imprinting, such a poor bond area may return some light to the observer, and appear somewhat brighter than the background. Care must be taken to provide the correct lighting so that it is less likely that such an example be mistaken as a good bond.

3) In the case of good bond, the area of the actual bond is seen to be torn by the pull test, showing a granular texture caused by a large multiplicity of individual regions each undergoing separate deformation and fragmentation.

4) Closer examination of certain bonds that show texture detail may indicate the presence of a different type of texture. This type of bond, called a "cold solder joint", is due to motion of the lead just as the solder turns to a solidus, causing a bond which is composed of very finely grained material. The small grains do not cohere strongly. The apparent reason this structure forms is that the solder cools below its solid point without solidifying, and when disturbed in this state, a vast number of sites quickly freeze even as the motion continues. Because of the continued motion, the sites do not form a strong matrix, but a spongy one, with a macular and gritty appearance, and a low strength because of its crumbly consistency. It is expected that few TAB bonds would show these cold solder joints, because of the co-supportive nature of the lead frame and its members. Nonetheless, although cold solder joints are not anticipated due to motion during the cooling of a liquid solder joint, it is possible that they would form in an insufficiently hot bond, only partly liquid from the start.

A number of different ways exist to perform optical metallographic inspection. Direct visual examination, preserved in the form of a photographic record, has been the standard method. In order to attain their maximum usefulness, these results must be quantified however, and this requires a lengthy ordeal of determining areas, either with the use of a planimeter, counting of grid squares, or some other method such as a cut-and-weigh process. Since optical imaging and image analysis was available in the SLAM equipment, it was much easier to determine optical metallographic bond areas in this manner. It should be noted that this is done without the use of any ultrasonic apparatus per se, but by using the optical video microscope equipment capabilities inherent in the SLAM, and the SLAM Digital Image Analysis routines, referred to hereafter as "SLAM Optical" when used together to form optical images and perform analysis of bond area fraction.

The SLAM uses a scanning laser focussed to a small spot, moving across a coverslip, or in some cases, directly across the target surface, to detect the minute changes caused by the transmitted acoustic wave. In the absence of the ultrasound, and also of the coverslip, the scanning laser beam can be used as a surface optical microscopic camera with the simple inclusion of a high-speed photodetector diode. The SLAM Optical image has the same magnification and resolution as the SLAM acoustical (ultrasonic transmission) image. Both are available as standard CRT images, and, by following the same protocols in the placement and the labelling of the samples, directly comparable images can be had of the sample acoustically and optically.

These images, SLAM optical or acoustic, can with equal alacrity be subjected to analysis of area fraction of the bond by means of the Digital Image Analyzer (DIA). The images are first stored to disk in the computer, in a grouping of four bond sites per image. Coverage of the solder TAB samples is thus complete with sixteen images per sample being stored. In DIA, a cursor box or window is placed around the bond site, thereby framing the area to be analyzed. A threshold level of brightness is selected, representing the difference between bonded and unbonded areas, and the image is discriminated between levels higher and lower than this value. Area fraction is then computed for the bond.

SLAM Optical evaluation was performed at an early stage, and gave encouraging results (See Section IV). However, further examination revealed that an artifact had been inadvertently included in the SLAM Optical results, and therefore, another study was also conducted, involving the traditional photographic methods.

The artifact was caused by another type of feature that appeared brighter than the dark field, namely reflective areas consisting of the curved menisci of reflowed solder that occasionally were found to occur within the DIA window. Unfortunately, the Digital Image Analyzer software does not encounter this phenomenon within its normal use with transmission mode acoustic images, and did not have the capability of discriminating these bright areas from those of interest. The following Figure 3.8 illustrates this.

These sketches illustrate four possible conditions that the bond pad might display. In the first sketch the original solder layer is seen, not having been reflowed. The second sketch shows the bond pad after reflowing; the solder takes on a round loaf-like shape due to its surface tension during its liquid state. The third sketch depicts the remains of an outer lead bond pad after the lead has been destructively removed during a pull test. The bond here is depicted as having been of wide and long dimension; an essentially perfect bond. The textured area is more reflective, and shows as a bright region in the metallographic examination. The fourth sketch shows a bond of shorter length. its textured reflective area is smaller. However, a bolus of solder seems to have been extruded, and formed into a shape which returns a specular reflection from a zone very near the analysis area. If this reflective area is included within the analysis window, then an erroneously high area fraction will be returned by the DIA software.

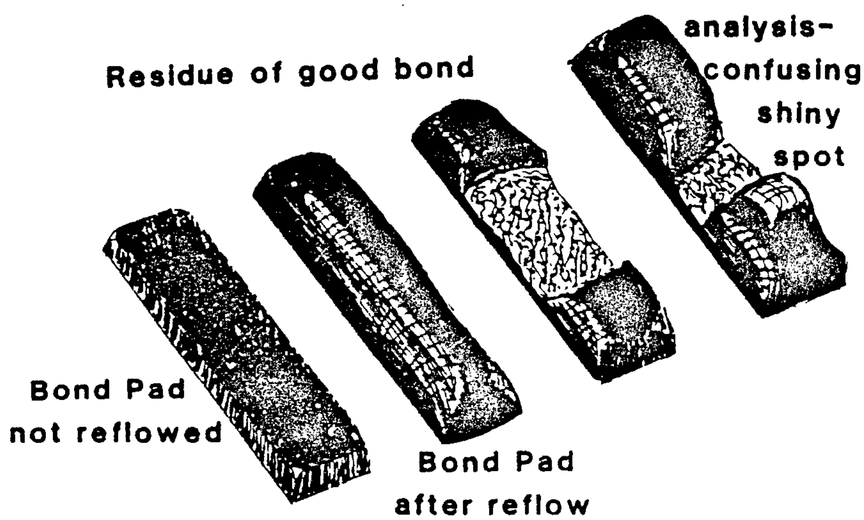


Figure 3.8. Illustration of bond pad conditions after pull test.

Although the DIA software in its role of reducing images to binary information does not discriminate this type of artifact, visual evaluation by the human observer serves quite well, though with significant extra labor for the determination of area fraction. Photographic views were taken using a Nikon F2 35mm camera with a Nikkor 55mm micro lens and bellows attachments. Enlargements allowed the determination of area fraction, using a grid-counting method. Where visual ambiguity from the photographs remained, it was resolved by the auxilliary use of a Nikon stereo microscope, altering the lighting and angle as necessary.

D. Typical SLAM Images of TAB

When the samples are inserted into the SLAM, acoustic images of the bonds appear directly on the CRT. Areas of the image that are bright indicate accordingly high level of acoustic wave transmission through the sample. Good bonding of layers will permit the maximum amount of ultrasound whereas disbonds will obstruct the ultrasound and cause the image to be dark. Anomalous samples can be easily indentified visually or instead, the data analyzed on-line by the image analyzer described above. In order to understand the acoustic images of good and bad bonds a series of example images are presented in Fig. 3.9 of TAB inner and outer leads. In these images, the grey scale has been converted to a simple false color map in which the lowest levels of acoustic transmission are red rather than black. This digital enhancement makes it less likely to misinterpret the image on the CRT from improper control settings in which shades of grey can be displayed so dark that they appear black. With reference to Fig. 3.9, inner leads a-k are imaged at 200 MHz while outer leads l-v are imaged at 100 MHz. The specific conditions that are indicated by these images are as follows:

a,j	-	disbonded leads and disbonded bond pads on chips. Note that j has excess over hang.
i,q	-	disbonded leads.
n,t,u,v	-	disbonded leads that are also misaligned.
f,g,k,o	-	partially or completely bonded but misaligned.
b,e,l,m	-	reasonably good bonds.
p,r,s	-	small area bonds
c,d	-	good bonds but solder bridging (short circuit).
h	-	partial lifting of bond pad.

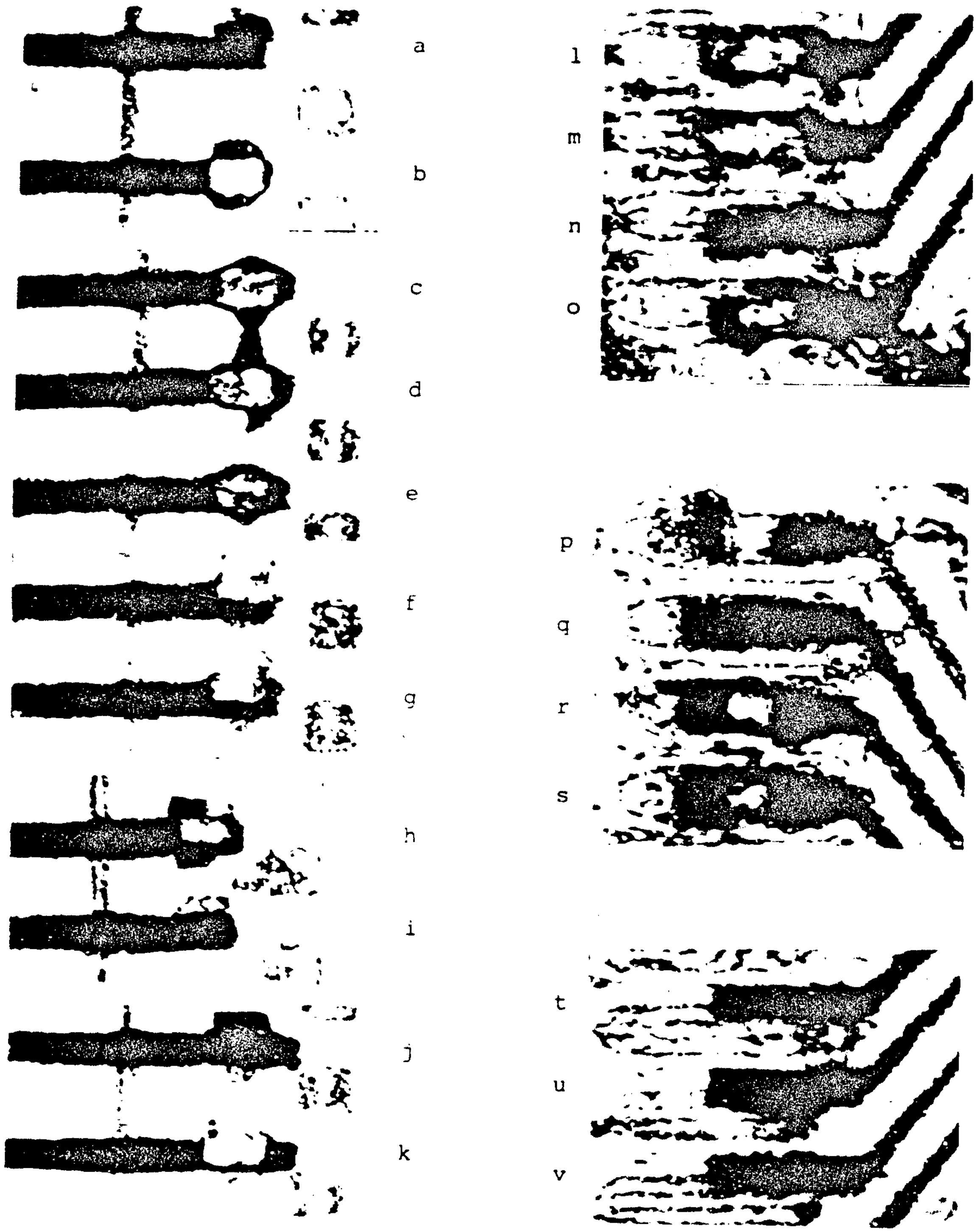


Figure 3.9. Typical SLAM images of inner lead bonds at 200 MHz (left column) and outer lead bonds at 100 MHz (right column). Note the width of the inner lead is approximately 3.7 mils and the outer lead width is 10 mils. See text for interpretation.

IV. RESULTS

A. Data Summary

The TAB bonded sample pieces which were involved in this study consisted of three types:

1) Inner Lead Bonds (ILB), of lead/tin (Pb/Sn) solder, having 64 bond positions, one of which (position 10) was vacant.
2) Outer Lead Bonds (OLB), of lead/tin (Pb/Sn) solder, having 64 bond positions, one of which (position 10) was vacant. These contain the same ILB structure as type (1) above.
3) Inner Lead Bonds (ILB), of gold/gold (Au/Au) thermocompression bonds, and gold/tin (Au/Sn) eutectic, 68 positions per sample.

Types 1 and 2 were the original subjects of the test. Type 3, the gold/gold and gold/tin samples, were included here to broaden this report, and provide some measure of reference to the type of bond more commonly used as of this time in the industry.

Within this study, there were included:

29	ILB (type 1) samples,	comprising 1,827 bond sites;
24	OLB (type 2) samples,	comprising 1,152 bond sites;
6	ILB (type 3) samples,	comprising 408 bond sites.

The distribution of acceptable and unacceptable bonds ranged well across the possible range of values, with the exception of the gold thermocompression and eutectic samples. These were obtained from MESA (see Section 2, Description of Samples) and were pulled also at the MESA facility. Only their inner lead bonds were studied, as these were the Au/Au and Au/Sn sites. Of these six samples, four were of very high quality, and consisted of essentially all high-strength bonds. The remaining two samples were deliberately bonded under low pressure conditions, and most of the bonds were defective; either completely unbonded, or compressed into a "mock bond" by partial conformity of their surfaces, but subject to rupture with the slightest provocation. Due to the high percentage of drop-outs, and the inability to perform reliable testing and handling without causing untraceable incidental damage, these two pieces were excluded from the series and only the other four were used. Also, a small number of type 1 and type 2 (solder ILB and OLB) pieces were of totally inadequate bonding character, and/or fell prey to inadvertant damage, and thus were excluded. The criterion used for a whole-piece exclusion was that the sum of totally unbonded leads plus the number of observational mishaps (as given below by exclusion code 2-9) exceeded half the number of positions on the die. The raw data from all excluded pieces is nonetheless included in the appendices.

The following three tables Table 4.1-4.3 summarize briefly the statistics of the study.

Table 4.1 Summary of data on solder ILBs

ILB Samples (solder TAB)

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	BONDING CONDITIONS: dwell time, temperature, pressure
ILB42-4	84.21	15.21	15.46	7.50	0.72	0.73	1	2	SS	MLM
ILB42-5	95.05	25.03	25.42	6.00	0.88	0.90	1	2	SS	MLM
ILB46-4	96.90	39.17	39.13	6.00	1.80	1.92	3	4	SS	HLH
ILB47-5	89.16	48.47	49.24	47.00	33.45	33.98	1	2	SS	HML
ILB48-3	89.78	45.89	49.33	24.00	12.45	14.38	6	5	GTE	HMM
ILB48-4	92.26	48.59	49.54	46.00	28.84	29.77	1	2	SS	HMM
ILB48-5	88.24	47.65	47.65	45.00	27.58	27.97	2	7	SS	HMM
ILB49-4	84.52	44.09	44.79	45.00	31.20	31.70	1	2	SS	HMH
ILB49-5	88.85	40.05	40.98	44.00	27.61	28.50	1	2	SS	HMH
ILB50-2	97.21	55.77	61.29	44.00	24.41	23.77	9	6	GTE	HHL
ILB50-4	96.59	67.42	68.49	49.00	29.50	29.97	1	2	SS	HHL
ILB50-5	97.21	64.73	65.58	40.00	26.92	27.79	1	2	SS	HHL
ILB51-3	88.54	49.43	50.63	61.00	27.16	28.03	1	2	GTE	HHM
ILB51-4	93.50	56.58	61.16	50.00	32.12	34.85	4	8	SS	HHM
ILB51-5	83.28	50.01	52.15	50.00	37.09	38.70	2	8	SS	HHM
ILB52-3	92.57	51.12	54.82	54.00	25.36	25.90	4	6	GTE	HHH
ILB52-4	81.42	53.55	54.40	50.00	43.03	43.71	1	2	SS	HHH
ILB52-5	96.90	47.69	49.23	55.00	38.75	40.00	1	2	SS	HHH
ILB53-2	100.00	41.41	45.43	27.00	11.92	13.28	6	5	GTE	MHL
ILB53-5	96.28	60.64	61.60	46.00	23.47	23.84	1	2	SS	MHL
ILB54-4	90.09	52.95	53.79	44.00	24.13	24.51	1	2	SS	MHM
ILB55-5	88.85	48.41	49.18	46.00	29.77	30.24	1	2	SS	MHH
ILB57-4	73.99	41.64	42.30	38.00	20.31	20.63	1	2	SS	LHM
ILB59-2	92.57	44.58	48.13	12.00	2.25	7.58	44	5	GTE	LML
ILB59-3	90.40	35.52	36.70	18.00	6.44	9.28	15	5	GTE	LML
ILB59-4	89.47	40.88	41.52	14.00	3.80	3.86	1	2	SS	LML
ILB60-2	95.36	50.19	47.25	13.00	4.17	8.90	33	5	GTE	LMM
ILB61-5	85.45	51.83	52.65	41.00	17.73	18.02	1	2	SS	LML
ILB62-5	80.19	36.46	40.23	41.00	16.73	17.64	4	6	SS	MML

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table 4.2 Summary of data on solder OLBs

OLB Samples (solder TAB)

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	BONDING CONDITIONS: dwell time, temperature, pressure
OLB16-2	97.15	33.64	34.04	141.00	11.62	12.00	1	2	GTE	LMH
OLB17-3	53.60	9.00	8.97	77.00	4.12	4.26	1	2	SS	LMM
OLB21-2	89.79	28.64	29.10	59.00	5.91	6.00	1	2	GTE	LHH
OLB21-3	95.80	46.08	49.43	50.00	32.59	32.75	4	6	SS	LHH
OLB24-6	83.78	10.73	11.02	31.00	4.08	4.21	1	2	SS	MLH
OLB25-5	77.78	16.04	15.91	44.00	7.12	7.03	2	7	SS	HLH
OLB28-2	77.78	20.66	19.33	83.00	11.56	12.33	2	5	GTE	MMH
OLB28-4	88.74	31.49	32.00	49.00	24.69	24.49	2	7	SS	MMH
OLB29-2	87.84	28.22	29.13	93.00	17.81	17.58	1	2	GTE	HMH
OLB29-5	83.78	32.26	32.77	32.00	9.47	9.62	1	2	SS	HMH
OLB31-2	93.69	32.49	36.49	103.00	17.80	28.48	23	4	GTE	HMM
OLB33-2	86.19	47.31	53.59	61.00	21.67	26.67	10	4	GTE	HHM
OLB33-6	50.45	19.90	20.21	37.00	7.47	7.59	1	2	SS	HHM
OLB34-2	92.94	58.31	61.25	67.00	29.52	34.35	5	5	GTE	HHL
OLB34-3	91.74	44.48	46.21	50.00	24.91	26.13	2	3	SS	HHL
OLB35-2	93.54	38.46	38.42	100.00	25.69	26.52	1	2	GTE	MHH
OLB35-4	93.54	60.92	61.88	120.00	75.31	76.51	1	2	SS	MHH
OLB35-6	95.50	66.09	66.89	125.00	65.97	70.37	3	5	SS	MHH
OLB36-2	70.27	27.04	23.89	44.00	3.64	5.68	22	4	GTE	MHM
OLB36-4	87.24	36.24	36.81	46.00	22.34	22.70	1	2	SS	MHM
OLB37-2	94.44	37.94	39.97	42.00	5.78	8.22	18	4	GTE	MHL
OLB37-4	57.96	18.33	19.86	40.00	4.86	5.58	13	9	SS	MHL
OLB38-2	93.24	33.79	31.40	30.00	3.97	5.18	13	4	GTE	MMM
OLB38-5	72.07	29.90	30.38	47.00	16.73	17.00	1	2	SS	MMM

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table 4.3 Summary of data on MESA Au/Au and Au/Sn.

MESA ILB (AuAu & AuSn TAB)

BONDING CONDITIONS: pres. & comp.

pull tested by

dominant exclusion code

# of exclusions w/codes 2-9

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	pres. & comp.
ILB-A-1	100.00	55.68	55.68	64.30	41.24	41.24	0	0	SS	M AuAu
ILB-B-1	99.21	74.67	74.67	64.90	50.27	50.27	0	0	SS	H AuAu
ILB-C-1	98.41	76.73	76.40	51.60	36.44	36.92	1	5	SS	M AuSn
ILB-D-1	100.00	85.96	85.96	46.50	38.41	38.41	0	0	SS	H AuSn
ILB-E-1	75.79	26.06	26.06	49.50	11.56	11.56	0	0	SS	L AuAu
ILB-F-1	69.44	15.19	15.19	39.20	3.75	3.75	0	0	SS	L AuSn

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Figure 4.1 Bond pad site after pull test of ILB42-4, pin 44.

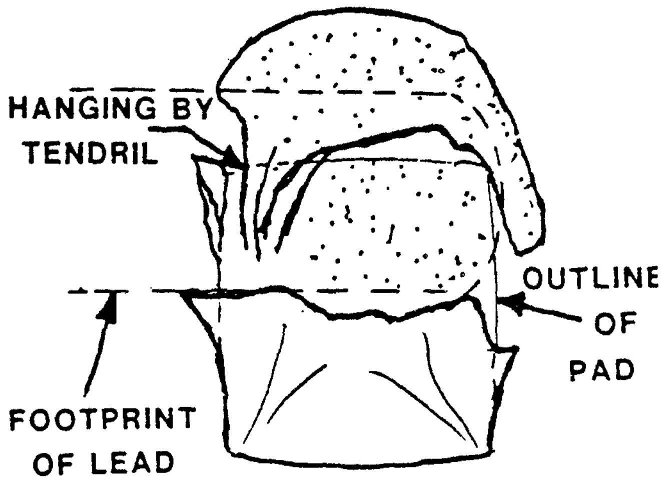


Figure 4.2 Analysis sketch of Fig. 4.1.

Figure 4.3 Bond surface of lead 44 on ILB42-4 showing no evidence of adhesion.

B. Evaluation of SLAM against Pull Test Data

Upon undertaking the pull test, it was quickly discovered that a number of pieces had extremely poor metallurgical properties. These poor properties were seen in those pieces which had been bonded under especially poor conditions; any ILB bonded at subnormal temperature was affected. Most bonds seen in the low temperature range samples were of low area fraction by SLAM. The few bonds showing modest area fraction were of intrinsically weak material, and yielded at lower than expected pull test forces.

A typical piece in this group was ILB42-4. This piece was chosen for close microscopic scrutiny to determine why this occurred. Upon examination at 320x and 640x optical magnification, the bond pad areas of this piece nearly all showed similar properties. The solder appeared to have been mashed out of shape while in a state that was not a fully mobile fluid or the solder froze out as a grainy solid in the course of the motion while its shape as a fluid was governed by a large amount of viscosity. Either case would be consistent with the phenomenon of a "cold solder joint". Certain pads were deformed in ways which disclosed even more fully this condition, for example pad #44 as shown in Figs. 4.1 and 4.2.

Here the solder bump appeared to have been smeared nearly off of one side of the pad area. All of the affected portion of the solder bump had a grainy texture, although this texture appears subtly different from that seen due to the rupturing action of a pull test. Furthermore, careful scrutiny reveals that this grainy area is wider than the beam lead, and further, that there appears a faint hint of contour that seems to mark the edge of the footprint of the beam lead. What is obvious from this is that the graininess is not due to pull test rupture since it also occurs where there was no lead. As a final observation, a bolus of grainy solder, including the part which must have extended beyond the beam lead, is nearly detached from the pad, being held on by only a thin tendril of solder. Had the solder been in the state of full liquidus, strong surface tension would have drawn this bolus back into the pad; furthermore, once having been so nearly detached, had it been bonded in any significant measure to the lead, it would be attached to the lead, and not the pad.

Reviewing the SLAM and pull test data, the following is seen: SLAM showed no bonding, and the pull test strength has a value of zero. Examination of the beam itself reveals that it carried no solder from the pad, and that in fact it had not been wetted by the solder, as seen in Fig. 4.3. Any discoloration or trace of solder appearing on the beam would have been put there by plastic abrasion against the semi-solid solder of the pad, and not by liquid transfer and alloying.

The great majority of the bond positions of the low temperature samples show this effect. Furthermore, what bonds in fact did form show an amount of granularity which indicates that they must have been intrisically weak. Pull test values were all very low if not zero. In the few cases where the SLAM

area fraction was more than a few percent, the bond involved had a strength of only a few grams. In the few cases where no pull strength was seen at all in spite of low or modest area percent given by SLAM, it is surmised that the bonding detected by SLAM was so intrinsically weak that it was destroyed in sample preparation, or during incidental contact while pulling neighboring sites. It is for these reasons that these pieces were excluded from the data set in some analyses. While every effort was taken to complete the tests and compile the data for all pieces, it was considered that in a few cases the data was simply much too skewed by even gentle handling, to be useful in some of the evaluations.

The following figures and photomicrographs illustrate the above. Below, in Figure 4.4 and 4.5, are pictures of lead number eight from ILB48-4, shown at 320x from the bottom side, and from the edge. In contrast to the poor bonding seen in the ILB42-4 sample above, significant amount of solder is seen to have come off the pad with the lead in this sample. SLAM evaluation rated this bond at 73.68 bond area percent; pull test gave a yield strength of 41 grams.

Figure 4.4 Bond Surface of lead 8 on ILB 48-4 showing good evidence of adhesion.

Figure 4.5 Side view of lead shown in Figure 4.4.

Similarly to lead number 44 of ILB42-4, neighboring leads, shown in figures 4.6-4.9, also showed the same lack of bond:

Figure 4.6 Bond pad site after pull test of ILB 42-4, pin 43

Figure 4.7 Bond surface of lead 43 on ILB 42-4

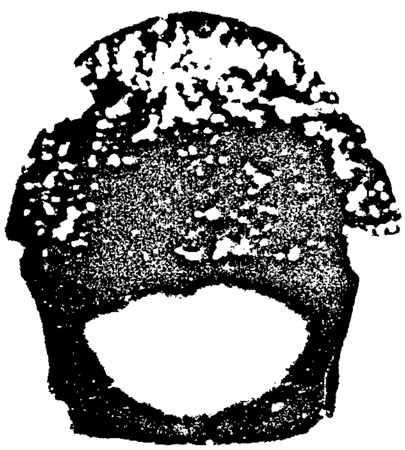


Figure 4.8 Bond pad site after pull test of ILB 42-4, pin 42

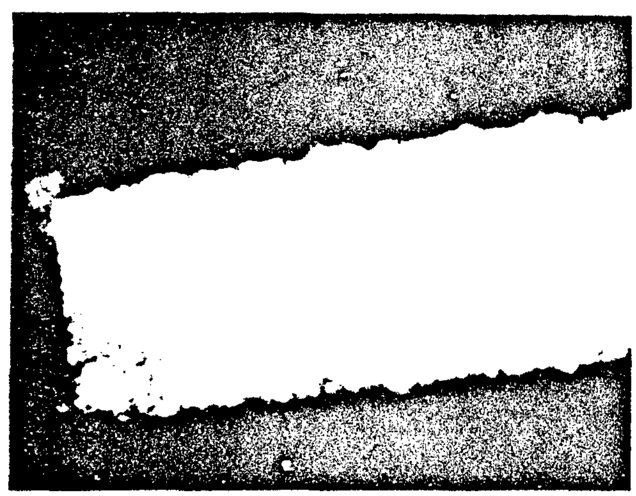


Figure 4.9 Bond surface of lead 42 on ILB 42-4

A number of ways exist to assess the value of SLAM data with regard to bond integrity. Pull strength is a commonly employed test for quality. The most obvious graphical method of comparing SLAM test results with those of the pull test is to plot one value against the other. If both were true and linear metrics of bond strength, then there would be no deviation from a straight line graph, except for perhaps some amount "fuzziness", or spread, due to data acquisition errors. If, however, this is not the case, there will be significant scatter in the data.

Using Figure 4.10 as an illustration, if one of the tests were to have serious variability, then each point plotted, though always correctly placed in, for example, the horizontal axis, would be found at various scattered positions vertically. There would be a "line of error" that was vertical. Conversely, if it were the other value that was always correct, then the vertical placement of the point on the graph would be correct, but there would be an amount of spread in the horizontal direction, causing a horizontal "line of error". If the degree of variability of both values were equal, then the point would occur somewhere within a "circle of error". Finally, if both values were subject to an amount of variability, with one having a higher amount, then the zone of error would be an ellipse. The problem is: all of the above conditions of variability give graphs which scatter in virtually the same way, as far as the eye can tell. Without additional information, it is not possible to know which set of values contributed to the spread, or whether both did; and, if so, to what relative degree.

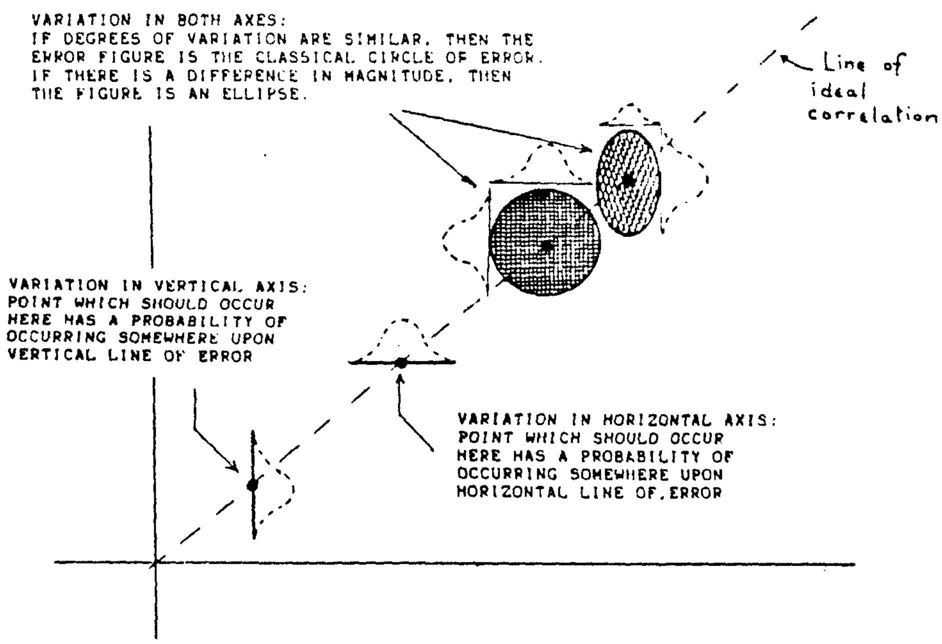


Figure 4.10 Example graph with scatter in data points.

The determination of whether the spread occurs in one data set, or the other, or both, can only be positively made by reference to some external standard. It is for this reason that other data in addition to SLAM and Pull Test data are also included; namely the optical metallographic examination after pull test. The possibility exists that one data set might at least suggest itself to be by some unusual property of its own. The discovery of just such an unusual property is discussed later in this section, and then in more depth in Appendix B.

Area of bond data were obtained for each lead on each sample and plotted against pull test values obtained on inner and outer lead samples. An example curve is shown in Figure 4.11. The graph of SLAM bond percentage plotted against pull test shows a monotonic relationship which tends toward saturation as the SLAM bond% values approach their upper extreme. However, there is quite obviously a large amount of data scatter seen in the graph. The saturation is due to the fact that bond strength is limited to that of a zone of rupture bound by the width of the lead bond and a length which is parallel to the lead length and which is dictated by the flexibility of the lead and angle at which it is pulled. It is not the total strength of the entire bond area but the peak strength of the zone of rupture as it proceeds along the bond during pull which dictates the yield strength of the bond. SLAM evaluation clearly shows the effect. Sample ILB49-5 is chosen for depiction since it is one of the samples that have a good distribution of both weak, medium, and strong bonds. Many other samples possess poorer distribution, and have either mostly weak or mostly strong bonds due to their method of fabrication, and thus do not show full continuity along this curve.

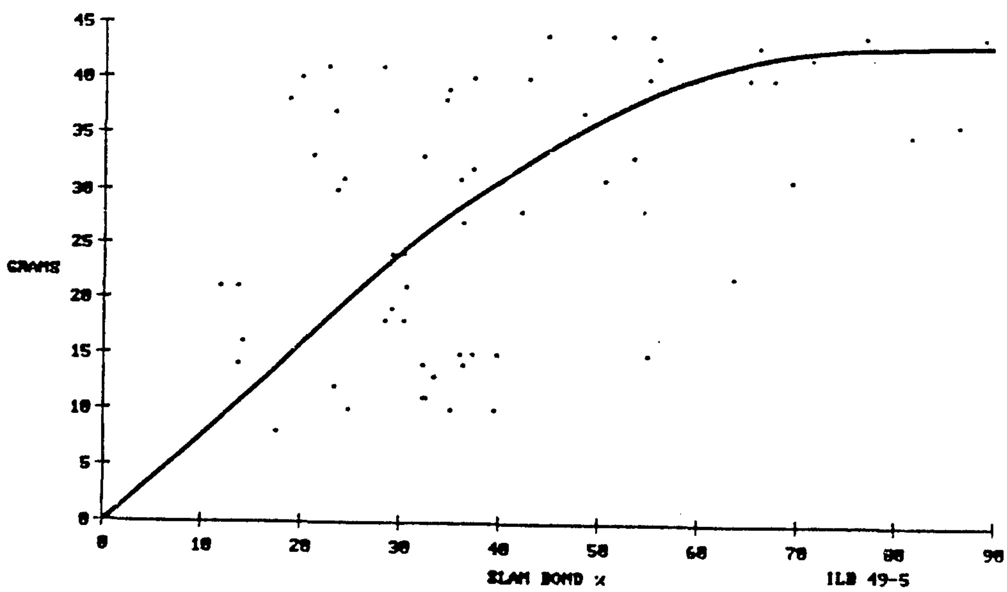


Figure 4.11 Uncorrected plot of pull strength vs. area of bond (SLAM) for ILB 49-5.

The graph of ILB52-4, shown in Fig. 4.12, contains members mostly positioned at high SLAM bond%, in the area of saturation. Some points here were also compressed by virtue of the gauge maximum reading.

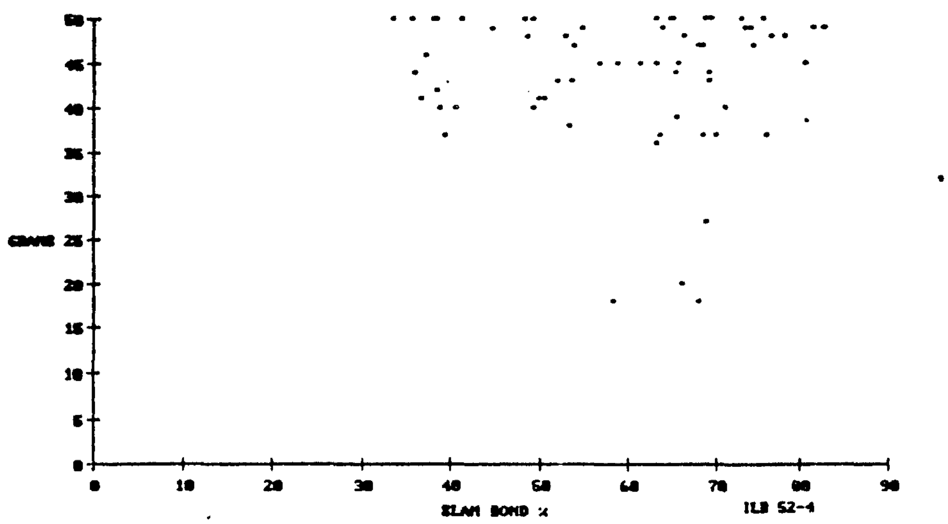


Figure 4.12 Uncorrected plot of pull strength vs. area of bond (SLAM) for ILB 52-4.

Sample OLB35-2, shown in Fig. 4.13, contains members both in the saturation region, and also some very weak bonds, but few in between.

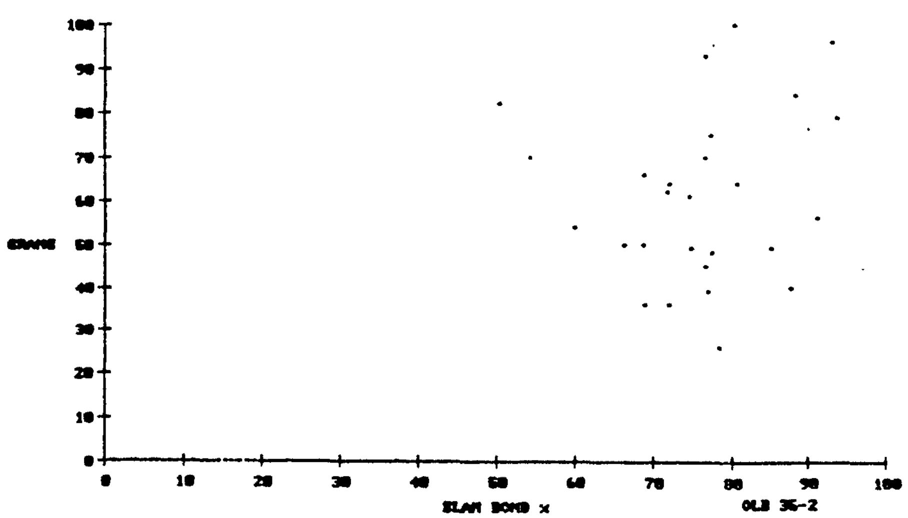


Figure 4.13 Uncorrected plot of pull strength vs. area of bond (SLAM) for OLB 35-2. Note that the data are clumped into two groups, one of which lies along the zero grams axis.

The graph of the ILB-B-1, shown in Fig. 4.14, (thermocompression) bonds lies at upper values, in the saturation region.

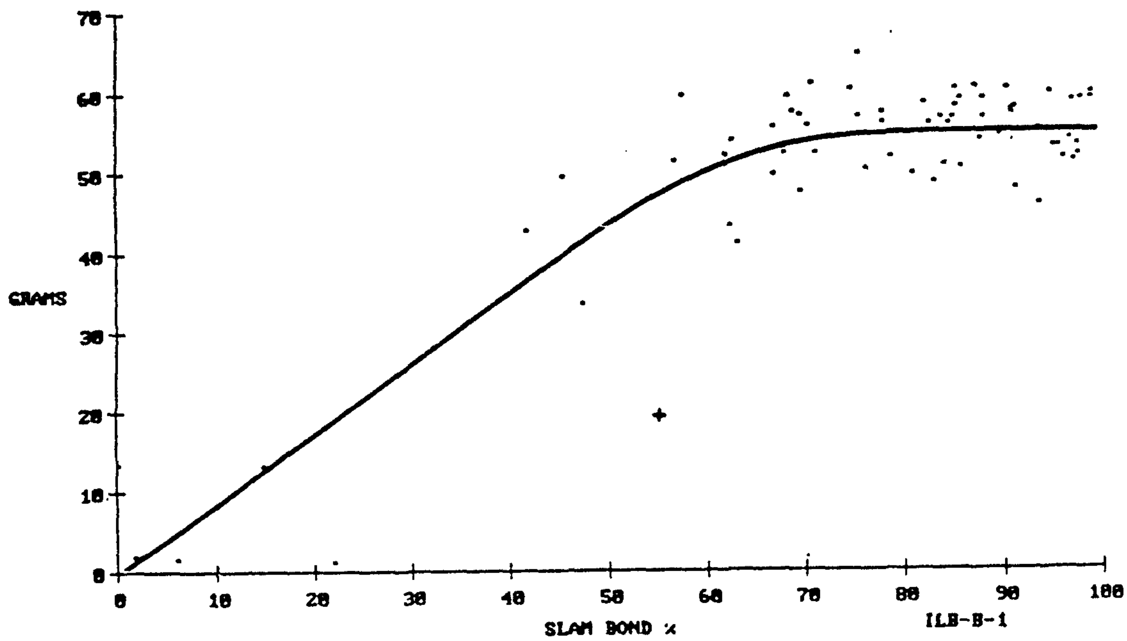


Figure 4.14 Uncorrected plot of pull strength vs. area of bond (SLAM) for ILB-B-1. The cross represents a lead which is susceptible to damage since it is located on the edge of a cluster of leads, thereby having no support to its other side.

A more detailed explanation of the rupture zone phenomenon is contained within Appendix B. In summary though, it can be said that the bond does not yield as a whole, but progressively peels. Since it is not possible to predict the exact dimensions of the rupture zone within the scope of this investigation, bond area was used as the SLAM parameter. In spite of the inaccuracies that result, we have found this to be a conservative judge of bond quality as will be shown below.

Graphs of all samples show a similar degree of scatter as in the above examples, so it was decided that it was necessary to find the cause and determine if better correlation actually existed beneath this data spread. One insight was that the locations of the bonding sites should have little to do with the bond quality unless there were unlikely systematic problems in the bonding process. That is to say, the positions should be fungible; although a

given lead may have a certain value of pull strength at a given position, there should not be a systematic difference in pull strengths at the various lead positions. Yet, it had been noted by one of us (JES) that the corner leads seemed to very often give low pull test values, compared to what would be predicted by SLAM. At this time, no reason was known, and the suspected phenomenon was given the name "the corner effect". A study was performed for the purpose of discovering such a positional effect. If there were found some periodic displacement in either the SLAM or the pull test data, it could possibly account for the observed data spread. The production of some of the graphical displays that follow requires that mathematical operations including averaging, sorting, normalizing, etc. be performed on the data. These methods should be understood as a prerequisite to complete translation of the graphs. Please refer to the postscript at the end of this section.

By investigating the pull test data alone, it was found that the values of pull strength were prone to vary, by a factor as high as three, from those values that were expected on the average, assuming that no positional variation existed. It was found that the variation was indeed positional, and had a period consisting of four minima per pass around the die as shown in Fig. 4.15. This figure shows the pull tests averaged over 25 samples as a function of position. The minima coincide with the corners of the die. This amount of variation is that associated with the hook-pulled solder ILBs, of which ILB49-5 is a member. An amount of "corner effect" variation is also seen with those inner lead bonds pulled with tweezers, and in lesser degree in the outer leads bonds (OLB) both tweezer and hook pulls. Referring to Figure 4.11 it is seen that approximately this amount of spread exists along the vertical direction.

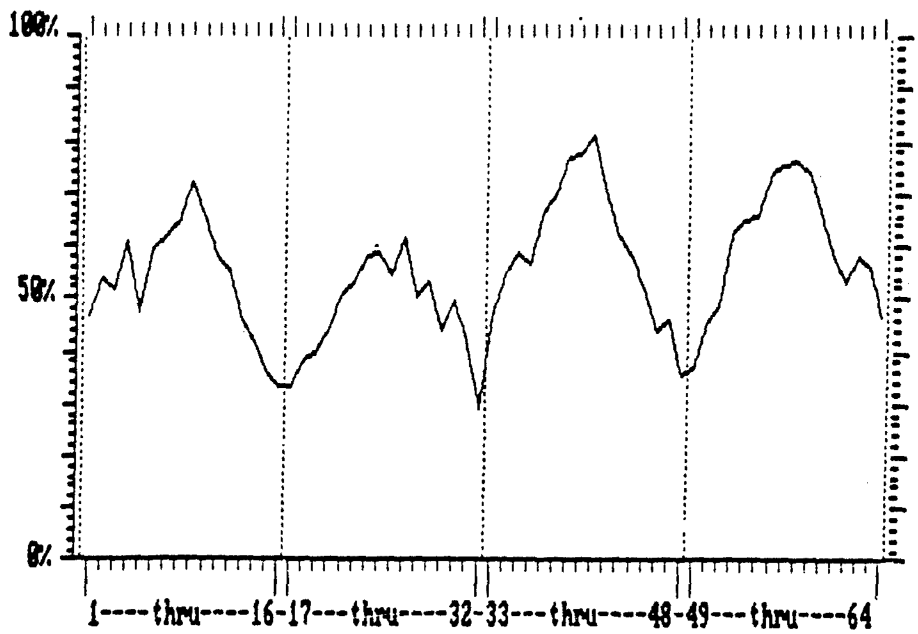


Figure 4.15 Normalized pull test data averaged for all ILB's as function of bump positions 1-64.

Because of the large number of dropouts in data from the tweezer-pulled samples (GTE) due in large part to incidental damage during the excision and bending necessary for the tweezer pull, it is not clear if a quantification of the amount of the corner effect for the tweezer-pulled pieces would be as meaningful. See Appendix B, with corresponding graphs.

Instead of being graphed against each other as in Fig. 4.11-4.14 above, data from SLAM and pull test may be graphed against lead position. In the following three figures, the normalized data are plotted for individual samples, as separate curves, against the position of the bond being tested. Figures 4.16-4.18 show one example from each of the three major groups of samples in the study including solder bonded ILBs, solder bonded OLBs, and thermocompression bonded ILBs.

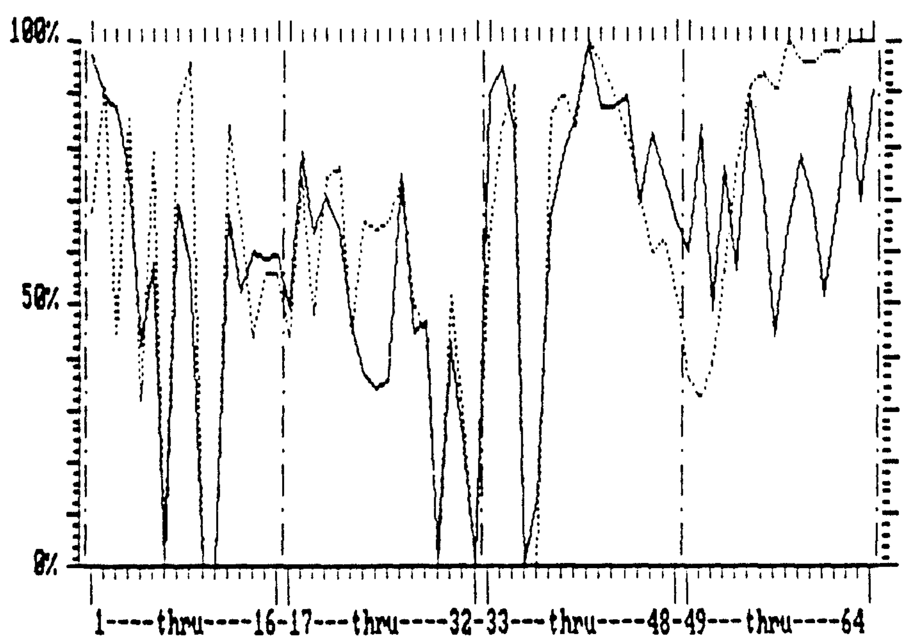


Figure 4.16 Normalized SLAM (-) and normalized pull test (...) for ILB51-4.

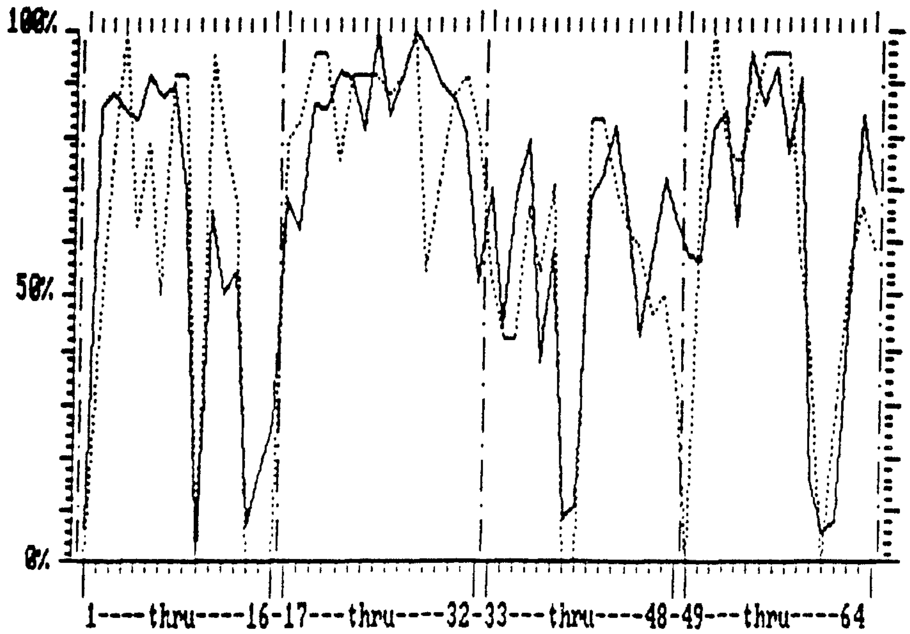


Figure 4.17 Normalized SLAM (___) and normalized pull test (...) for OLB 35-4.

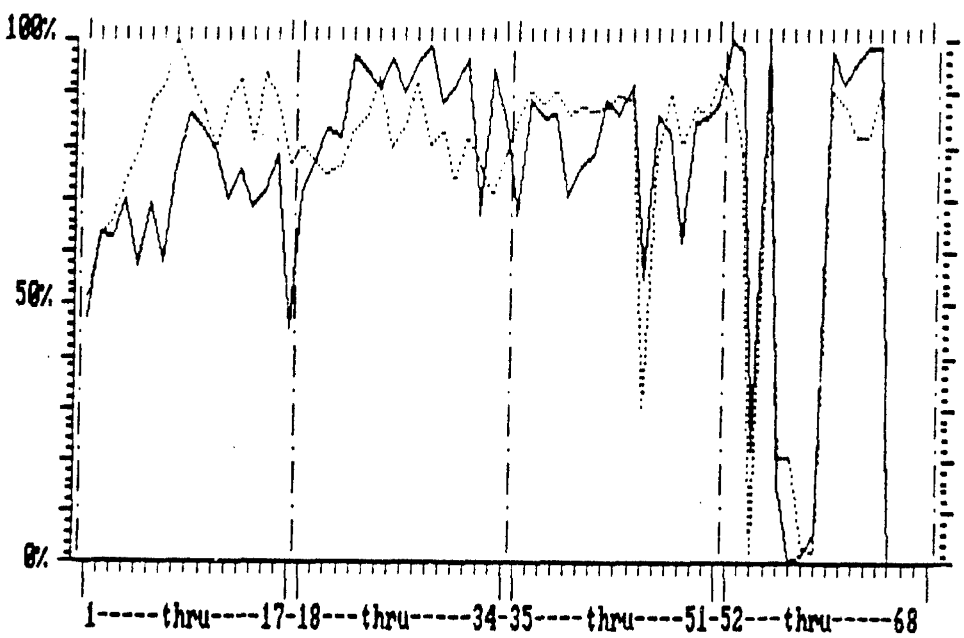


Figure 4.18 Normalized SLAM (___) and normalized pull test (...) for ILB-B-1.

The data, both SLAM and pull test, are normalized so that their vertical ranges are of comparable scope. It is plain even from casual inspection that the data of SLAM and that of the pull test correlate well. There also plainly exists an amount of data scatter. However, since there is so much vacillation of the data of both types, due to real variations in the strengths of each bond, there is not much chance of perceiving, in any single sample, some kind of systematic reason for the apparently random disparities between the SLAM and pull test data.

Figures 4.19-4.23 that follow are graphs which use the same axes as the preceeding. However, instead of single samples, the normalized averages of both SLAM bond percent and pull test values are now plotted together, for each of the groups of samples including hook-pulled thermocompression ILBs, hook-pulled solder OLBs, tweezer-pulled solder OLBs, hook-pulled solder ILBs, and tweezer-pulled solder ILBs. These graphs are composed using two artifacts to aid in cosmetic appearance. First, in both the inner leads and outer leads of the solder TAB samples, position ten is vacant. Since data for this position is handled digitally as a zero value, and not as a "null", the graphs would show a sharp misleading drop to zero at position ten, implying a systematic failure at this position. To circumvent this, position ten is artificially loaded with the average of its neighboring positions nine and eleven. Second, to avoid an excessively ragged curve, "neighborhood smoothing" was employed using two adjacent positions and eight adjacent positions. Available in the Appendix B are the curves without this smoothing, both standing alone, and superimposed with the smoothed curves for comparison. An inspection will show that the smoothing in no way disturbs the general validity of these graphs, but merely serves to minimize distraction from the main observations. Note that the MESA samples differ in that they have 68 instead of 64 positions, and also that position ten is not vacant, but is occupied. The following, Fig. 4.19 shows the normalized SLAM and normalized pull test for MESA ILBs A-D.

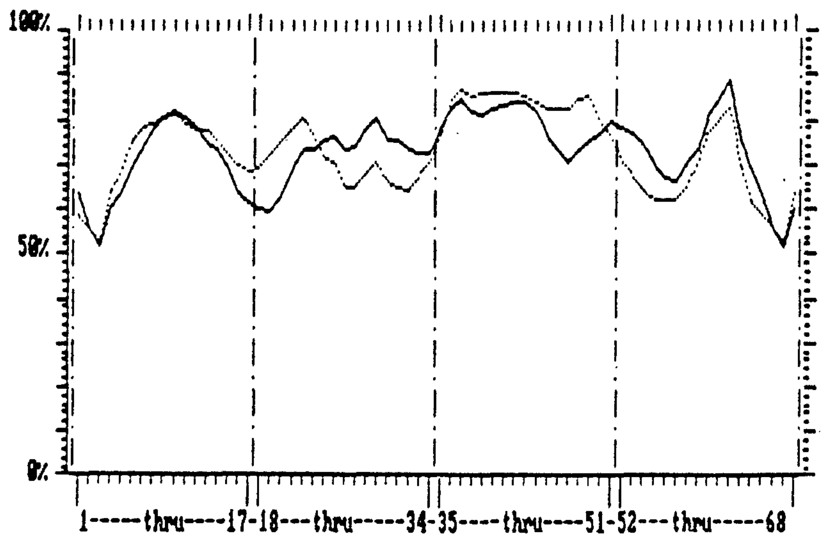


Figure 4.19 Normalized SLAM (___) and normalized pull test (...) for MESA ILB's A-D (smoothed x 2)

The thermocompression ILB samples from MESA included in the first of these graphs contain only four sample pieces, and thus the smoothness of the curves is not as good as it would be were more samples included; individual variations are more prominent. This is especially so for position one and position sixty seven, where a large coincidence in the four samples produced the lowest value in the curves. Of special significance here is that in spite of the small number of samples, the SLAM and pull test data correlate extremely well with eachother. This is likely attributable to factors that mimimize the importance of "corner effect" and whatever other disturbing influences tend to make SLAM and pull test deviate. In the thermocompression samples, the beam leads appear to have the more square cross section of approximately 1.4-1.5 mils of thickness by about 3.0 mils of width, compared with about 1.0 mils thick by 3.6 or 3.7 mils wide in the solder TAB samples. The MESA samples also contained an additional polyimide band, which may have been instrumental in decoupling the ILBs from the dog-legged portion of the lead frame. In addition, much higher intrinsic strength of the MESA bonds may have significantly reduced their susceptibility to incidental damage, during the phase of sample preparation, causing better correlation between the tests by preventing degradation between tests.

Among the solder TAB outer lead bonds, those OLBs pulled by GTE with tweezers have SLAM and pull test curves which seem virtually identical, although displaced from eachother; the Sonoscan hook-pulled OLBs show a firmer hint of the corner effect. In the case of the Sonoscan hook-pulled samples, the pull test values show an oscillation over every period (each of the four die edges constitute a period), with pull strengths that dip to minima near the corners. GTE samples were pulled with the use of tweezers in order to do this, the lead must be caused to have a free end for the tweezers to apprehend; thus it becomes necessary to cut the leads at some point. If the cut for the OLBs is close enough to the bond sites themselves then the effects of a "dog-leg" in the lead is minimized because a large portion of it is removed. If the tweezers are placed close to the bond areas, little corner effect can be seen. Conversely, the Sonoscan pull tests were accomplished with the use of a hook, implying that the length of the lead, and any "dog-leg" within it that is not constrained, will contribute to the corner effect. It may be this consideration that accounts for the difference. A review of the pull test methodology from GTE shows that the razor used was positioned "just forward of the bonds on the chip" which implies some amount of lead loss, especially as an adequate amount of room must have been left to allow for "rocking the knife back and forth". The following two figures, 4.20 and 4.21 show these OLB families.

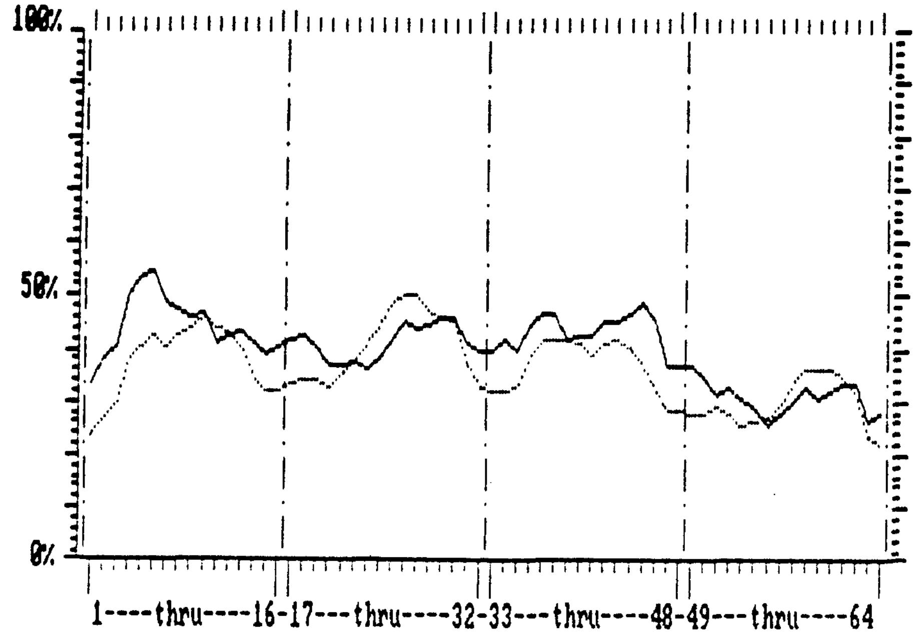


Figure 4.20 Normalized SLAM (___) and normalized pull test (...) for hook pulled OLBs (smoothed x 2).

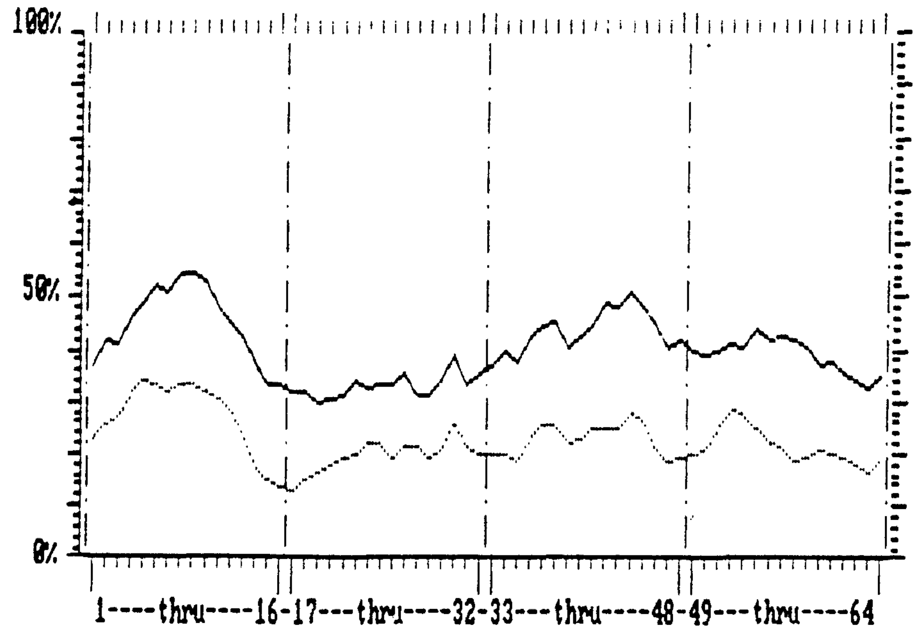


Figure 4.21 Normalized SLAM (___) and normalized pull test (...) for tweezer pulled OLBs (smoothed x 2).

The "corner effect" becomes most obvious when reviewing the ILB samples both from Sonoscan and GTE pull tests. Although the GTE method proceeded with the use of tweezers, the length of the leads was long enough to contain the full dog-legged portion, or a major fraction of it. Therefore, while the GTE ILB samples show a corner effect that is a bit less pronounced than that in Sonoscan ILB samples, this is what is to be anticipated, considering the relative geometries involved. The extreme and pronounced nature of the corner effect, especially as visible in the hook-pull ILB samples, demonstrates perhaps in the most convincing way that a pull test is a non-ideal measure of the strength of a bond. It is plainly demonstrated that the result of such a test will systematically vary with respect merely to the position of the bond, and not strictly its strength. It is plain that a pull test cannot be used as a direct linear metric. This is not to say that the pull test is valueless; rather that, due to geometrical biases, and methodological difficulties, the pull test is not truly a quantitative measure and thus cannot be used as a scalar metric of bond strength, nor by extension as a faithful gauge of another evaluation method such as SLAM! The following two figures, 4.22 and 4.23, show these ILB families.

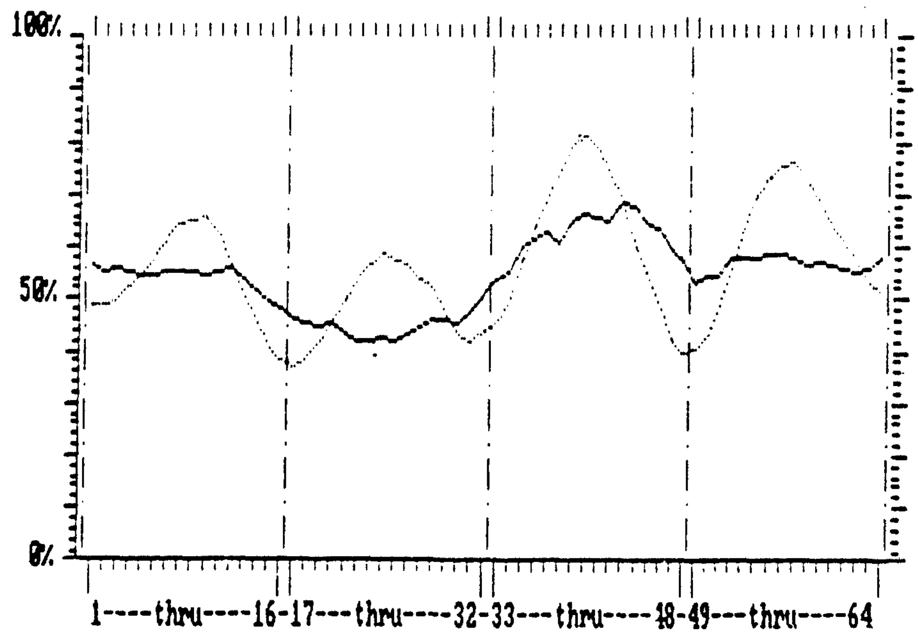


Figure 4.22 Normalized SLAM (-) and normalized pull test (...) for hook pulled ILBs (smoothed x 2).

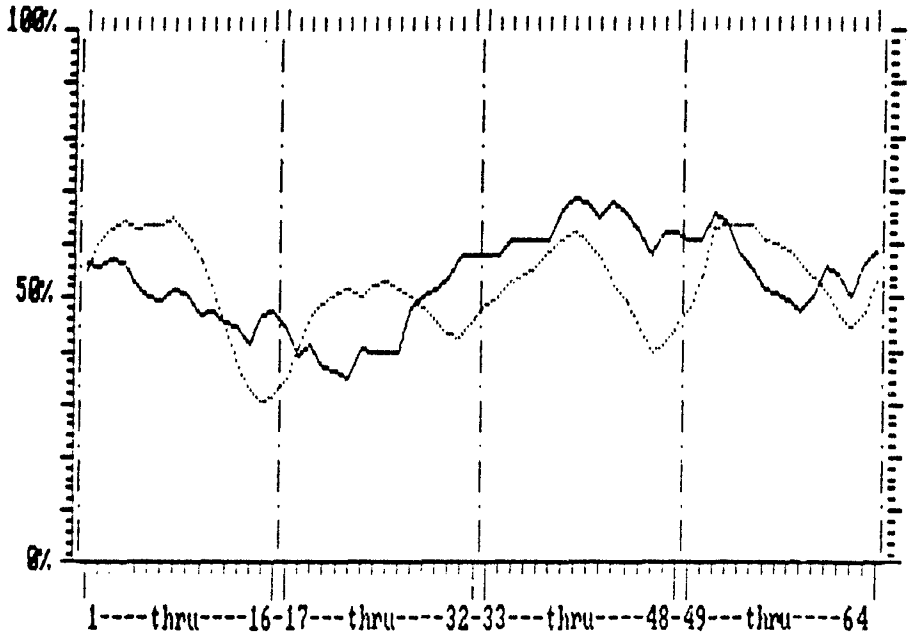


Figure 4.23 Normalized SLAM (___) and normalized pull test (...) for tweezer pulled ILBs (smoothed x 2).

It will be evident from these graphs that distinct patterns exist which indicate the presence of various effects. The presence of these effects is difficult to perceive within a single sample, because the emergence of the resultant trait depends upon nearly random co-factors. Thus, while certain leads near the corners of the die are prone to pull test at lower apparent strengths, this depends upon factors such as how much of the dog-leg in the lead is available to exert its influence, and therefore upon how the lead was seized. In the case of a tweezer pull, the lead must be apprehended very close to the bond to eliminate any crooked geometries in the lead. This must be done without causing incidental damage during excision, and lead-forming. In the case of a hook pull, it is difficult to imagine any specific method that would totally eliminate the corner effect.

At the beginning of this evaluation, it was not realized at what a precise and minute scale these effects could operate and therefore it was not possible to avoid them. Moreover, it is not certain that, even knowing of the delicacy needed to eliminate the corner effect, that it could be done to a reasonable measure, owing to the intrinsic relative crudity of the available pull test

instrumentation. Ordinary pull test equipment serves adequately for the type of wire bonds it was originally engineered for, but might now prove to be less than satisfactory for meeting the special needs of TAB bonded parts, especially those with non-straight beam leads.

In any individual sample, while there is a probability that a test value might depart from an expected value by a given amount, based upon its location on the die, the fact is that any given lead might or might not deviate by such an amount. The process leading to the deviation is stochastic. Thus the inspection of individual samples may not yield a pattern unless the observer is able to discern the presence of a fluctuating trend. The easier method of course is to take the average of many samples, to then obtain the pattern by plotting or elsewise analyzing the results. By determining the size of the deviation, one obtains the amount by which some lead (at a given position) might deviate from the expected value. However, one cannot broadly apply this number as a type of "correction factor" on a lead by lead basis to straighten the graph, precisely because of the stochastic nature of the effect. If a given lead, at random, did not participate in the effect or if it participated to less than the expected amount, attempting to correct it would only displace the value in the opposite direction.

While the pull test cannot be used to strictly quantify the SLAM test, it may serve nonetheless, within the constraints of its variable nature, either to corroborate the SLAM test results, or conversely, cast a measure of doubt upon them. What is found is a distinct corroboration. With the exception of the one above graph (ILB, pull tested by Sonoscan, with hook) where the corner effect has become so pronounced as to make the curve of pull test oscillate strongly around the SLAM curve, the curves track each other closely not only in shape, but largely also in scale.

By the methods described above, it was conclusively shown that:

1) SLAM and pull testing are not identical with respect to evaluating these types of lead bonds.
2) One or the other, or perhaps both, have significant spread, or scatter, in their values.
3) The pull test is shown, by reference only to itself versus lead position, to have sufficient scatter to account for the scatter found in the plots of SLAM versus the pull test.
4) SLAM versus the pull test shows the effect of saturation of bond strength, as would be expected if the pull test were affected to some measure by a "peel test" character.
5) To the extent that the corner effect does not distort the data, the pull test strongly corroborates SLAM as a nondestructive evaluation tool.

Some interesting secondary conclusions should be mentioned at this time which, although not the primary purpose of the study, might bear useful consideration in the general field of interest. By the use of the "smoothing" operation over the range of neighboring positions comprising half a period of the corner effect frequency, it is possible to eliminate its effect from the graphs. Having done this, what is left could be a flat horizontal line if no further periodic effects remain. However, if there is information at some other frequency, then it would persist and be detected as a nonflat curve. If the effect was seen only in one evaluation method such as either SLAM or the pull test, as did the corner effect, then most logically it would be an artifact of the evaluation method. If, however, it is seen in both, then this would imply that something in the bonding process actually leads to an uneven product. For example, a non-planar thermode would cause consistent groups of leads to be poorly bonded. Similar effects would be caused by uneven heating of the thermode and uneven pressure.

When the corner effect spatial frequency was removed from the preceeding data, a number of interesting results were obtained. First, the shapes of the SLAM and pull test curves became essentially identical. Further, their vertical positions, though normalized, also virtually coincided, with the single exception of the OLBs, where some unexpectedly low strength values pulled down the averages. It is seen from examining the data that extensive incidental damage occurred prior to the GTE tweezer pulls, which account for these low values.

Secondly, periodic influences do in fact occur, at a period of once around the die. Furthermore, each pattern is very precisely recapitulated by both SLAM and the pull test data within each of the sample classes, making it a virtual certainty that peculiarities in bonding process have been discovered. The precise nature of this systematic bonding process variation is not known; it is easy to speculate however that the distribution of heat or pressure somehow are skewed. Perhaps the angle of the thermode surface, or the platform holding the part, or both were slightly tilted, or the heat nonuniform in a repeatable manner.

The following seven figures, 4.24-4.30, show the convergence of the pull test curves with the SLAM curves after the corner effect has been suppressed by the smoothing method. For the purposes of complete equivalence, the SLAM curves are also processed with the eight-neighbor smoothing, although since little variation occurs in the SLAM curves at this frequency, there is little effect to be seen. Full sets of curves for comparison are available in the Appendices.

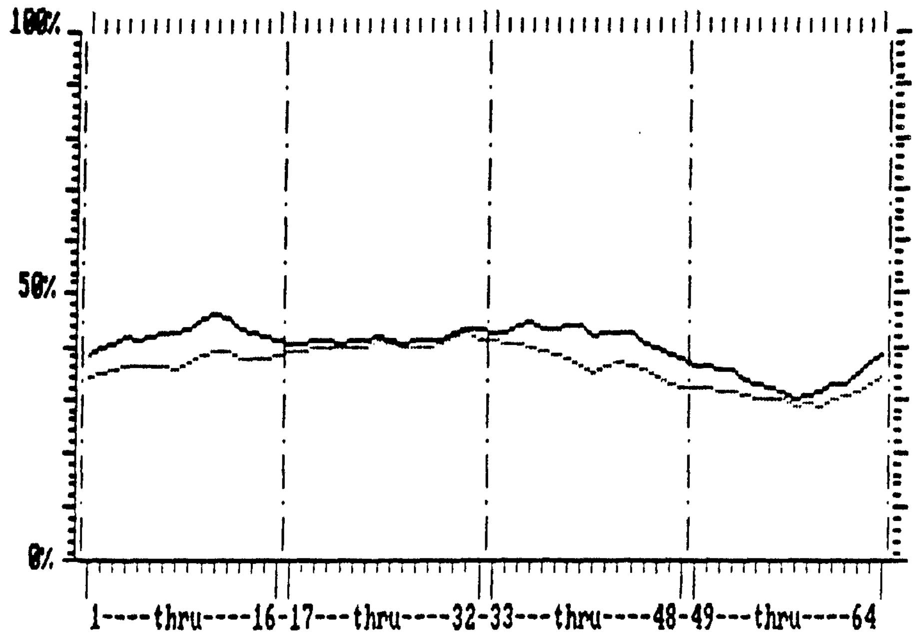


Figure 4.24 Normalized SLAM (___) and normalized pull test (...) for MESA ILBs A-D (smoothed x 8 to remove corner effects).

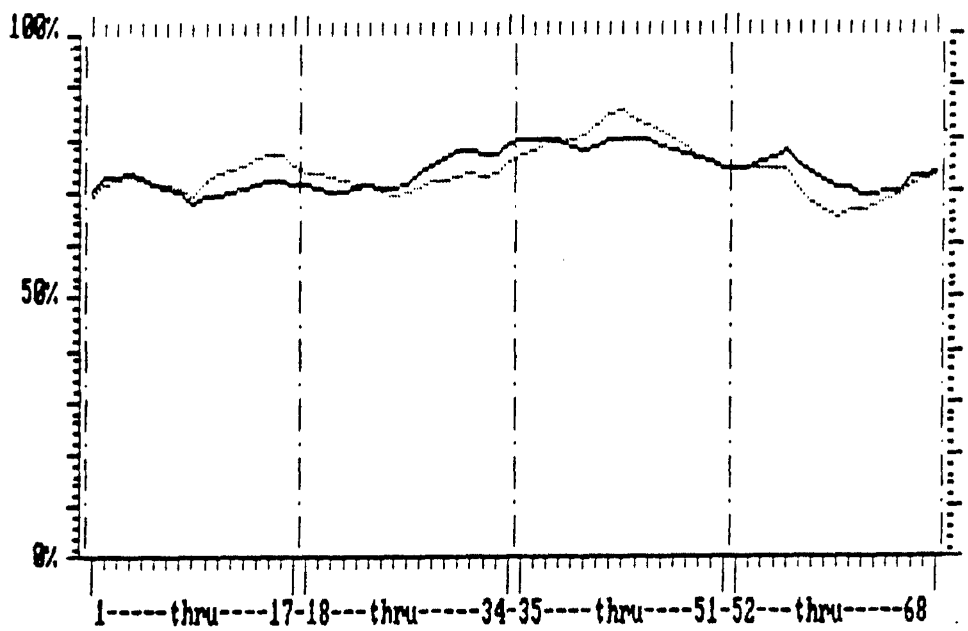


Figure 4.25 Normalized SLAM (___) and normalized pull test (...) for hook pulled OLBs (smoothed x 8 to remove corner effects).

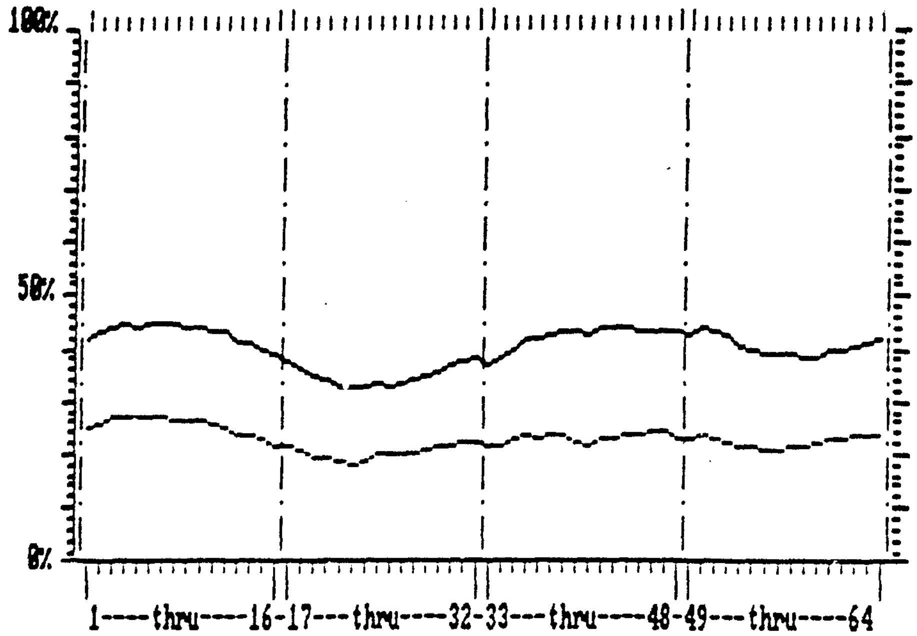


Figure 4.26 Normalized SLAM (___) and normalized pull test (...) for tweezer pulled OLBs (smoothed x 8 to remove corner effects).

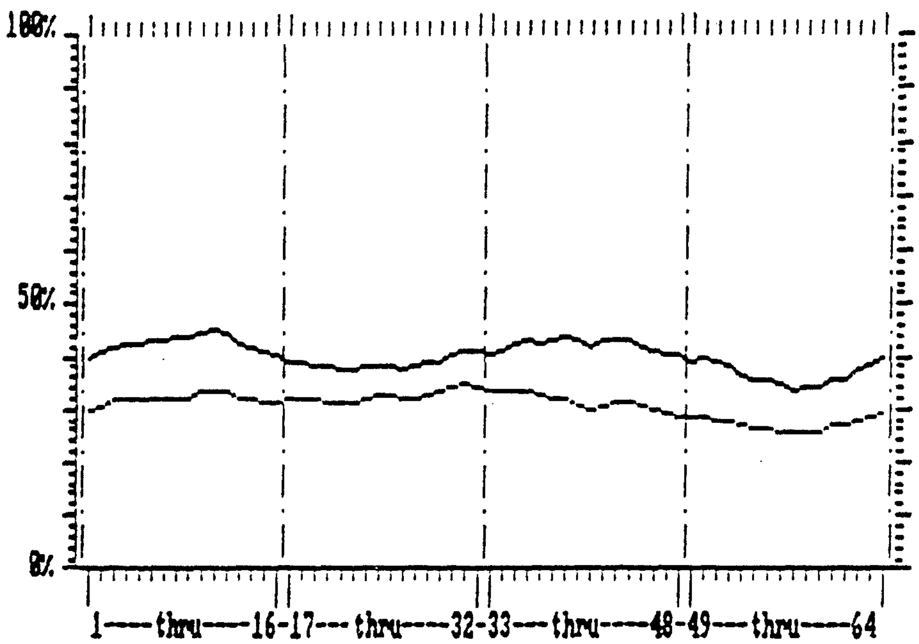


Figure 4.27 Normalized SLAM (___) and normalized pull test (...) for all OLBs (smoothed x 8 to remove corner effects).

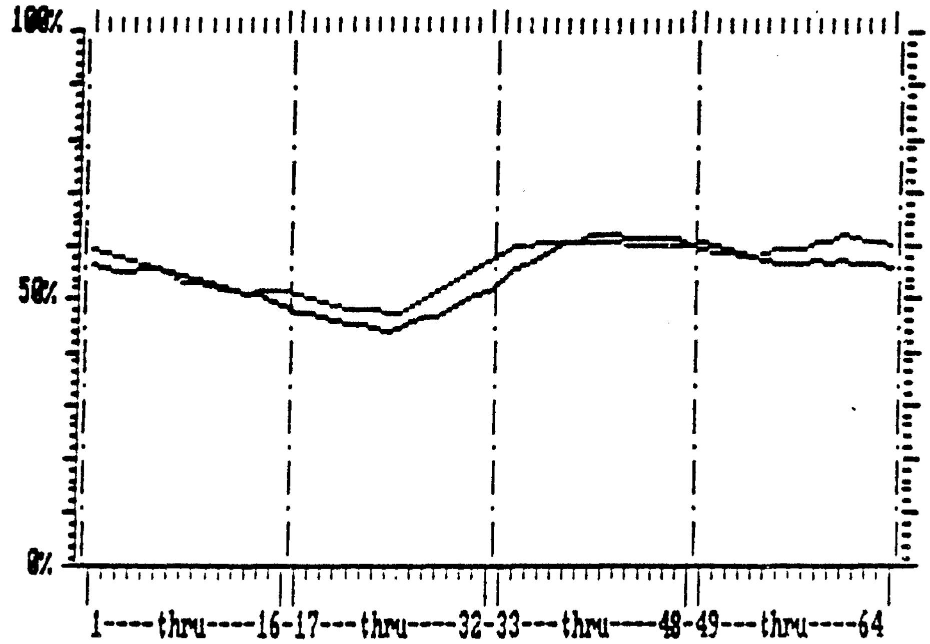


Figure 4.28 Normalized SLAM (___) and normalized pull test (...) for hook pulled ILBs (smoothed x 8 to remove corner effects).

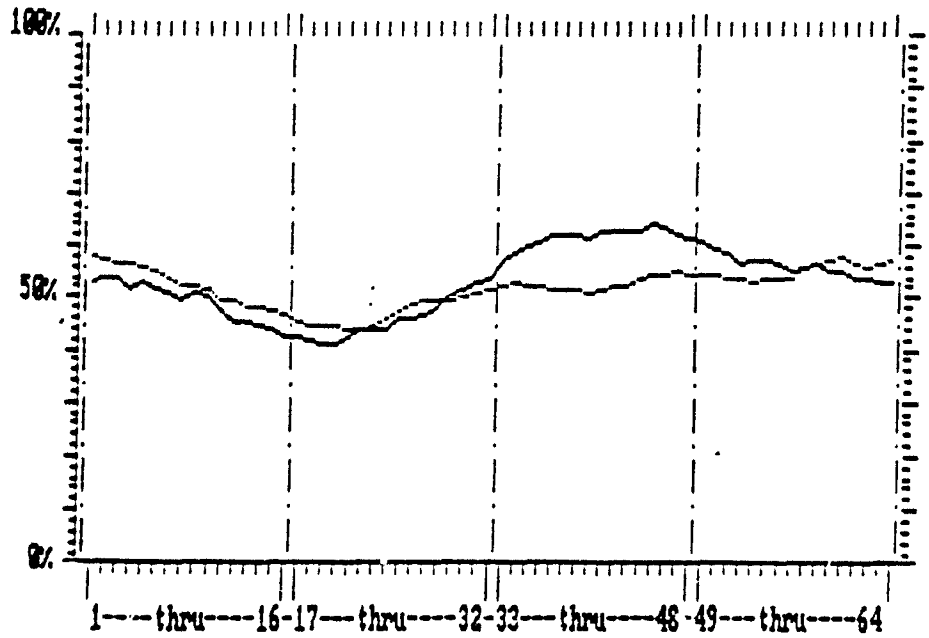


Figure 4.29 Normalized SLAM (___) and normalized pull test (...) for tweezer pulled ILBs (smoothed x 8 to remove corner effects).

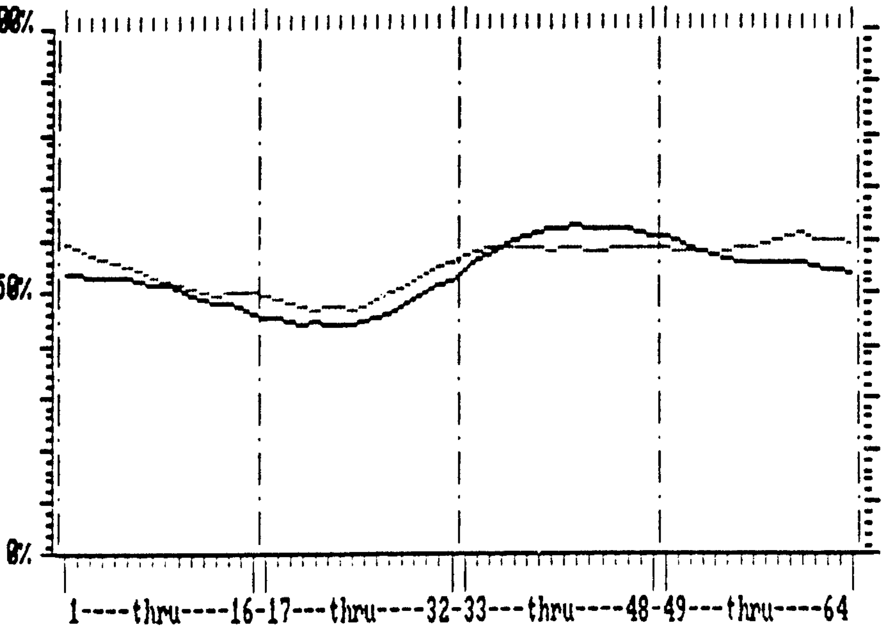


Figure 4.30 Normalized SLAM (___) and normalized pull test (...)for all ILBs (smoothed x 8 to remove corner effects).

Of interest also would be a probability factor indicating how "strong" a bond might be when subjected to a pull test if previously it had been examined by SLAM and found to possess a certain bond area. Such a set of curves, if made with the data of the solder TAB samples of this study, would be very conservative at the minimum, for two reasons:

1) The samples have different pedigrees of origin that are prone to large variance in stregth; yet, since such an index as this would imply absolute strength values, normalization cannot be used in any direct way to circumvent these disparities. Hence, the strengths found would be diluted by those from the intrinsically weaker samples.

2) The "corner effect" will further pull down the reported strengths.

Despite these weaknesses, curves of this type were prepared as shown in Figs 4.31 - 4.35. Note that in preparing those curves, corner and near corner data points were deleted from the the data set when it was suspected that the bond was damaged prior to pull test. Surprisingly, they indicate very favorably for SLAM evaluation as a predictor of pull strengths of respectable magnitude. One

element of interpretation should be explained. As the probability that a bond will meet a benchmark pull strength grows with its increasing SLAM bond, it eventually meets a ceiling, since the probability cannot exceed 100%. Whether a bond can meet a benchmark pull test strength depends upon whether that strength is meetable. A benchmark of 5000 grams obviously can not be obtained. How fast the curve meets the 100% mark if meetable, (in other words, the slope of the curve), is the measure of confidence of being able to meet that benchmark. However, as larger and larger values of SLAM bond percentages are encountered, fewer and fewer samples are seen to have so large a bond percentage. Hence the population becomes sparse, and statistically less precise. If a data point or points, having non-ideal characteristics happens to fall within this sparse population, its effect will seem more dramatic than if it were to exist as a tiny fleck in a larger data set. Therefore, as curves progress from left to right along the graph, they may begin to waver because of the higher contribution of statistical noise. A curve can therefore proceed up to its ceiling (at 100% probability), and although constrained by the impossibility of it exceeding 100%, it may jitter around (necessarily below) 100% when SLAM values continue to increase. This must be understood to be due to statistical noise, and not naively interpreted to mean that as SLAM bond% further increases, the probability of meeting a pull test strength actually begins to rise and fall a few percent in an erratic fashion. In fact, the ceiling has been reached and all the rest of the curve is disposable, since it is statistical noise only.

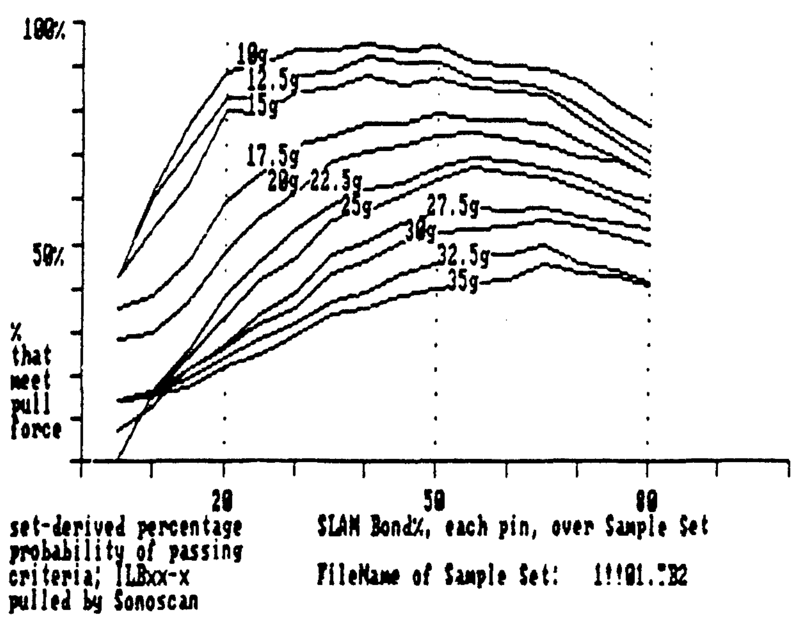


Figure 4.31 Probability (vertical axis) of a bond meeting or exceeding a pull strength (of 15-35g) based upon SLAM measurements (horizontal axis). Sample set is for ILBs, hook pull tested.

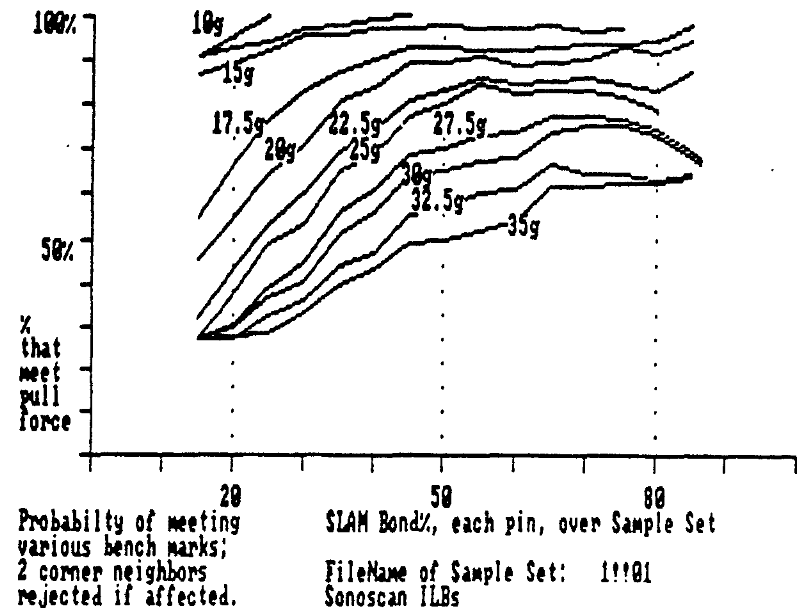


Figure 4.32 Same as Fig. 4.31 except that 2 corner neighbor leads were deleted if necessary due to corner effect or damage.

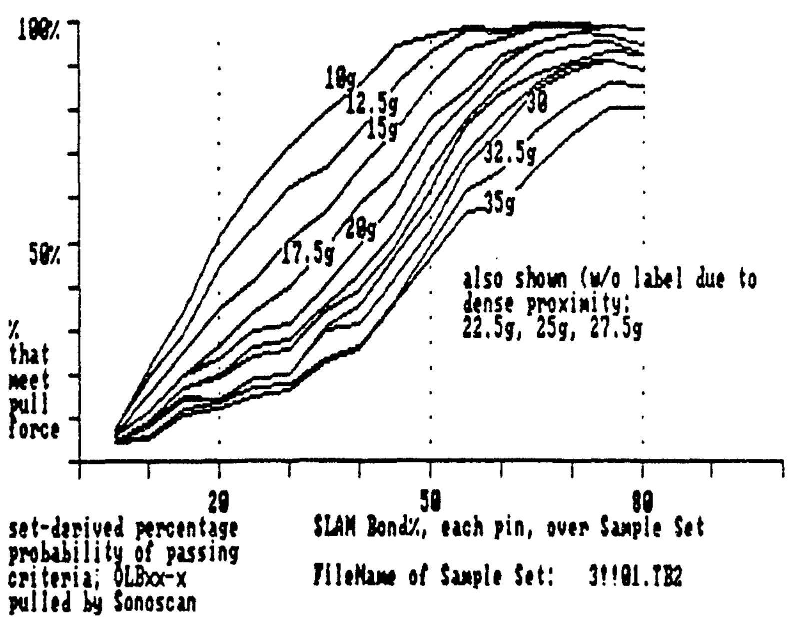


Figure 4.33 Probability (vertical axis) of a bond meeting or exceeding a pull strength (of 15-35g) based upon SLAM measurements (horizontal axis). Sample set is for OLBs, hook pull tested.

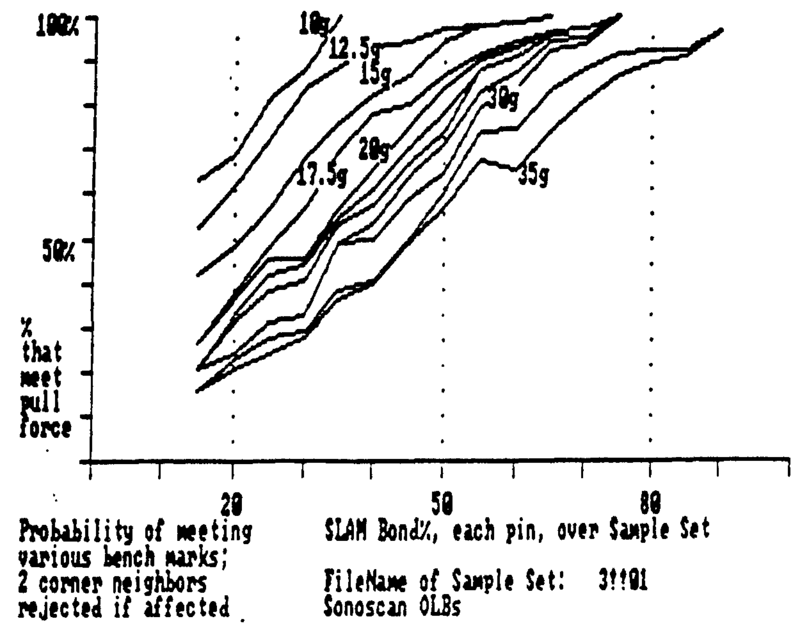


Figure 4.34 Same as Fig. 4.33 except that 2 corner leads were deleted if necessary due to corner effect or damage.

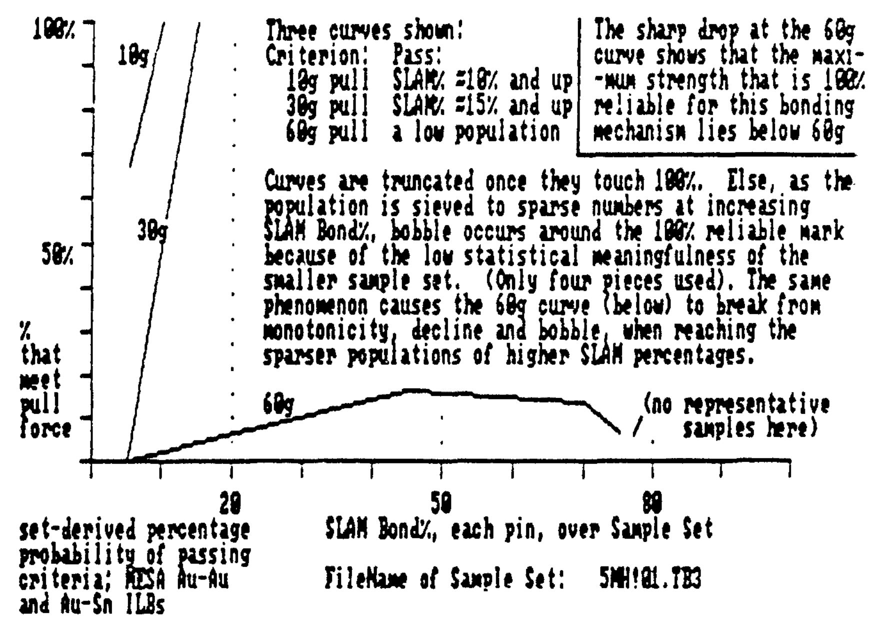


Figure 4.35 Probability of a bond meeting or exceeding a pull strength (10-60g) based upon SLAM measurements. Sample set is for MESA ILBs which are Au/Au and Au/Sn.

In Figures 4.30 - 4.34, probability curves are presented both with and without a small amount of compensation for the corner effect. Although from prior curves it is evident that the corner effect is strong as far from the corner as five or six positions, the degree of compensation was limited to two positions only in the interest of being conservative.

Because of the stochastic nature of the corner effect, no simple arithmetic factor could be used for compensation. Instead, if a position was first or second from a corner, and showed strongly that it had been affected, it was merely eliminated from the data set for purposes of the following comparative graphs.

C. Evaluation of SLAM Against Optical Metallographic Inspection

In order to confirm the findings from the SLAM versus pull test, another study was undertaken comparing SLAM with an optical metallographic evaluation of the bonding sites after destructive pull test had been completed. The purpose of this second type of evaluation was to seek a correlation between the bond area shown by SLAM, and that which was disclosed by examining the lead and pad surfaces after the pull test.

This study occurred in a number of phases. The first evaluation employed the digital image analyzer of the SLAM, operating not upon the acoustic image, but upon the optical microscopic image of the bonds. Results here were encouraging, in that they showed a linear correspondence between SLAM and the optical metallurgy; in contrast with the saturation characteristic of the pull test data vs. SLAM.

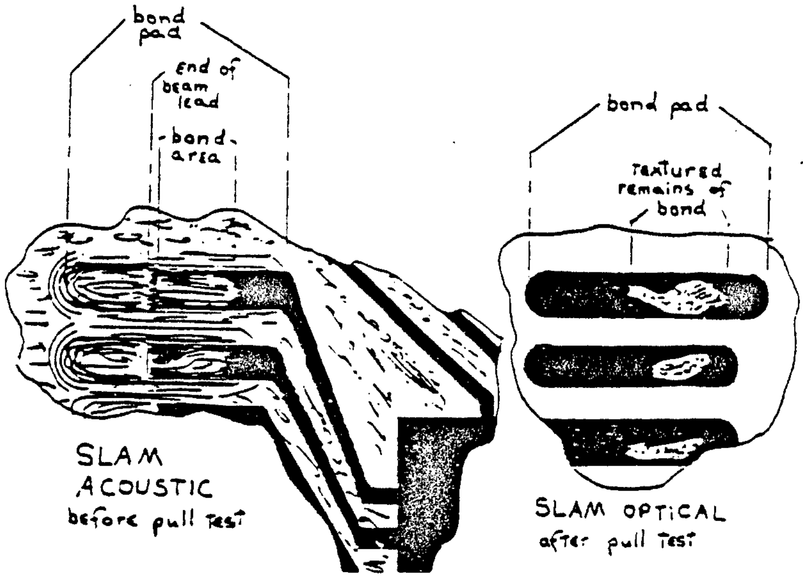


Figure 4.36 Guide to interpreting SLAM acoustic images with respect to metullurgy of bump after lead pull test.

The photomicrographs, Figs. 4.38 - 4.48, which follow, are of three types; SLAM acoustic, SLAM optical, and optical by means of an ordinary optical microscope. In order to more easily interpret the meaning of the SLAM acoustic and SLAM optical images, see above Figure 4.36, in which the elements of the images are described. Here a sketch shows a section of a SLAM acoustic image prior to pull test next to a section of a SLAM optical image of the same figurative piece

after pull test. In these illustrations the outer leads are being examined. The acoustic image shows bright areas where bonding is good; there is little loss due to transit of the ultrasound through alternate media, and so the amount of acoustic power transmitted is higher. More power is scattered away and absorbed where no bond exists between the beam lead and the bond pad, so these areas are dark. In the SLAM optical view, regions that had been bonded show texture and are thus bright against a dark field. The bonded areas correlate well in these two views.

When the original optical metallographic examination using SLAM optical evaluation was performed, it was not recognized that the artifacts caused by intrusive shiny areas existed (Section IIIC, the Methodology for Optical Metallographic Examination). These artifacts caused a number of points to appear to have higher bond areas by SLAM optical than by SLAM acoustic where the artifacts did not exist. An earlier plotting, shown below in Figure 4.37, portrays some of the points that ranked anomalously high.

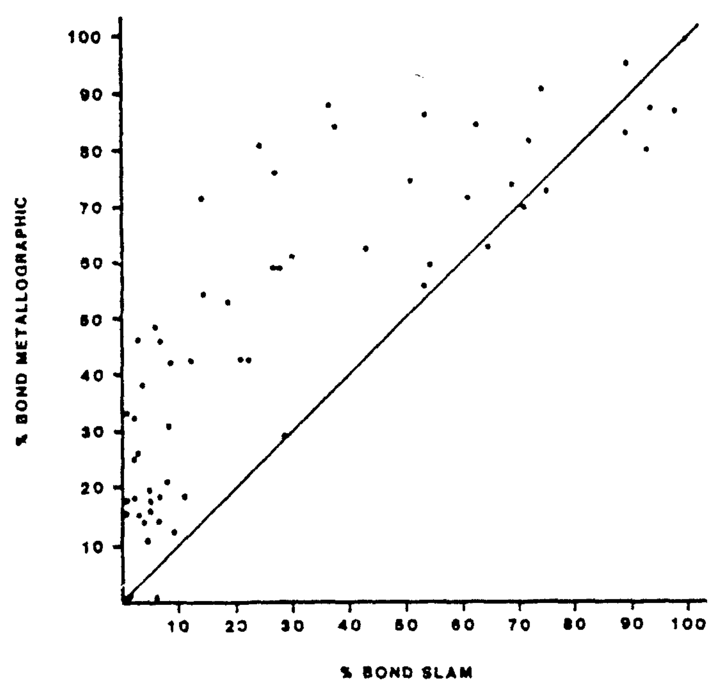


Figure 4.37 Sample 16-2 graphical plot of bond area as determined by SLAM vs. metallugical examination post pull test as determined by the image analyzer. Note that the smaller area bonds appear to have been larger at some time in the sample's history and prior to the pull test. The solid line shows the theoretical equality of the two measurement techniques in the absence of sample damage and measurement error.

For reference purposes, the SLAM acoustic (left) and SLAM optical (right) of OLB16-2, presented above, can be mapped upon the view of the outer lead bond substrate shown as a whole, taken through standard optical microscope, in Figure 4.38 below.

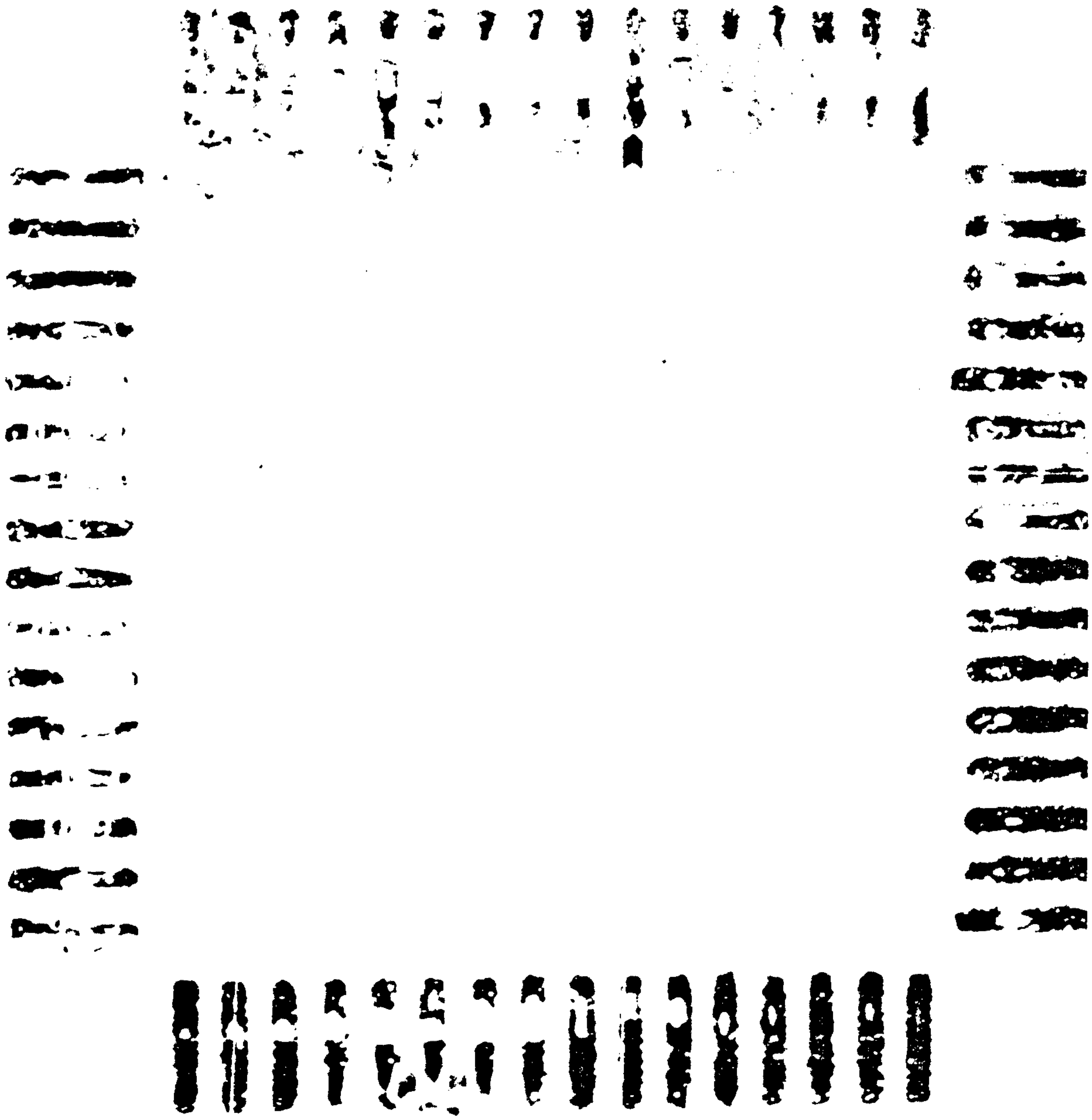


Figure 4.38 Photomicrograph of OLB 16-2 after pull testing to reveal the bad sites.

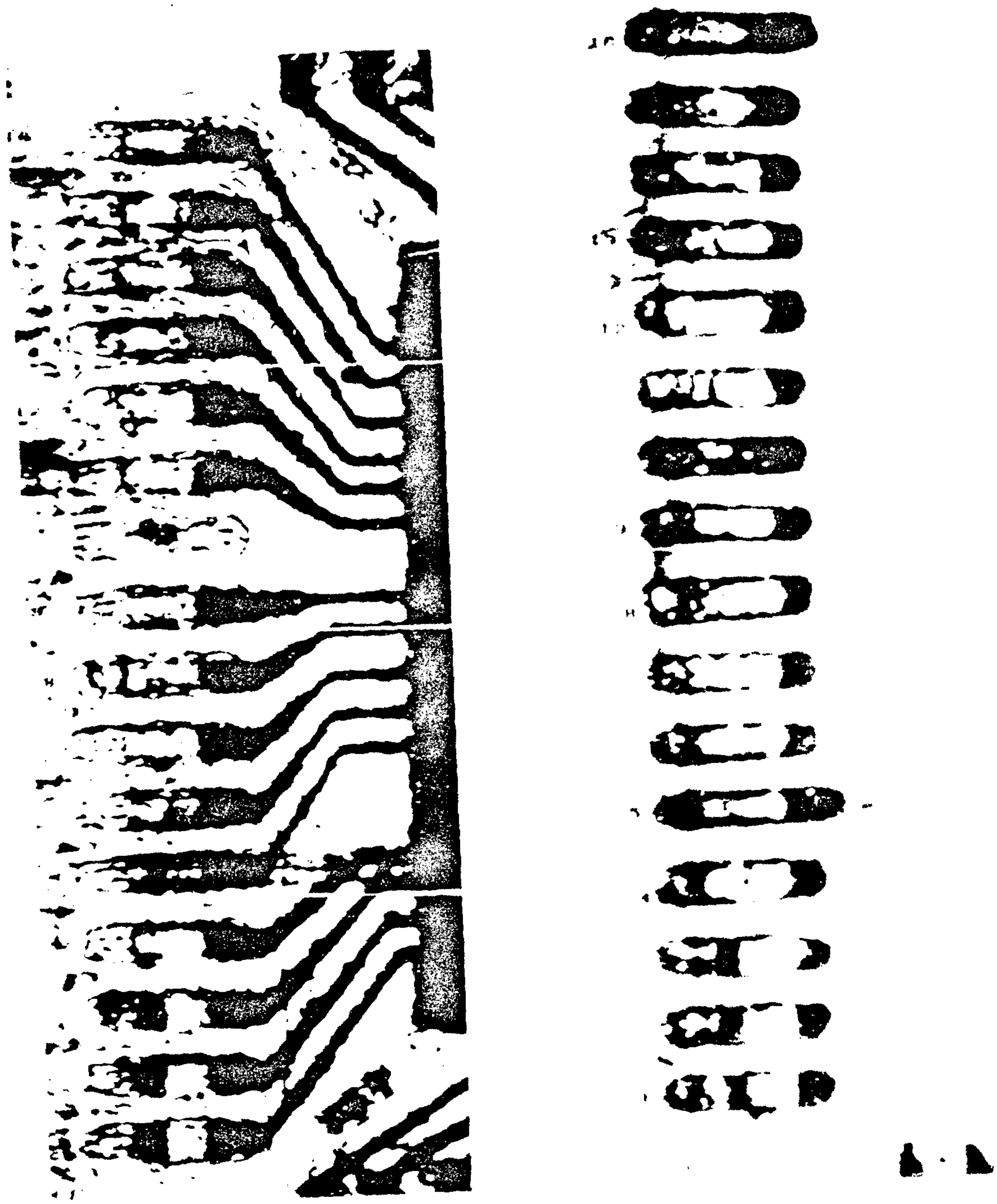


Figure 4.39 SLAM (100 MHz) and corresponding optical images of OLBs on OLB16-2, pins 1-16.

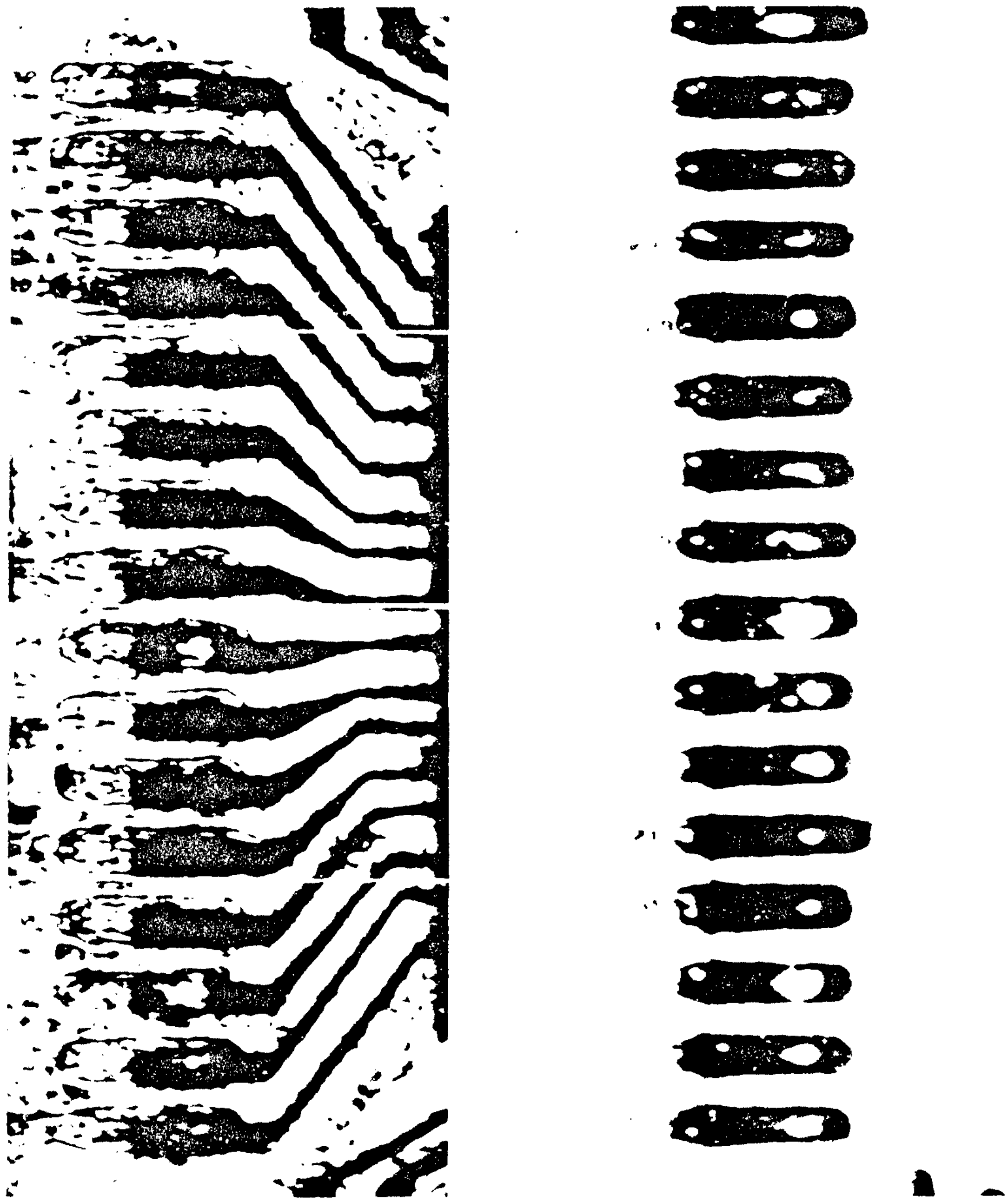


Figure 4.40 SLAM (100 MHz) and corresponding optical images of OLBs on OLB16-2, pins 17-32,

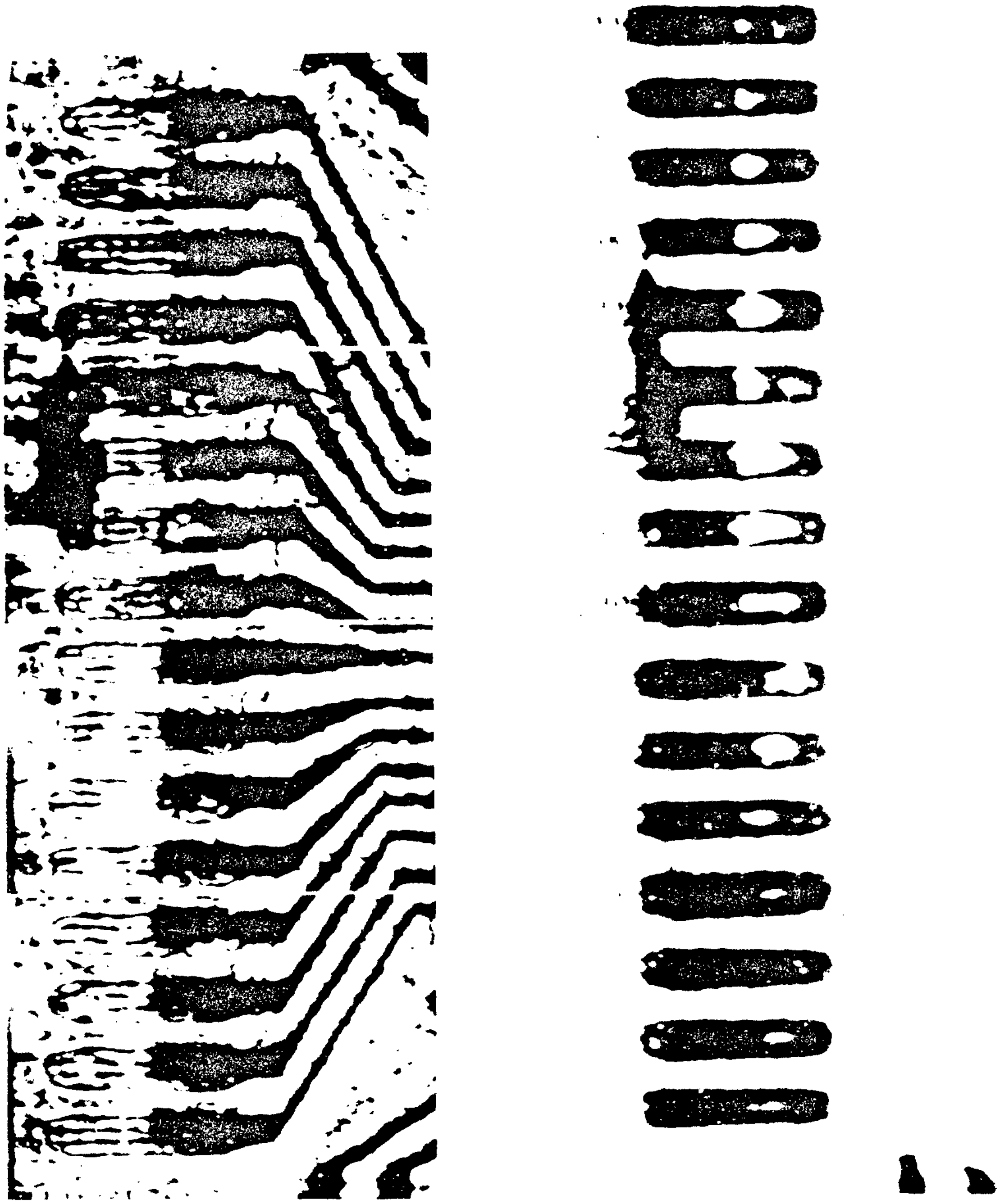


Figure 4.41 SLAM (100 MHz) and corresponding optical images of OLBs on OLB16-2, pins 33-48. Note solder bridging between pins 42 and 45.

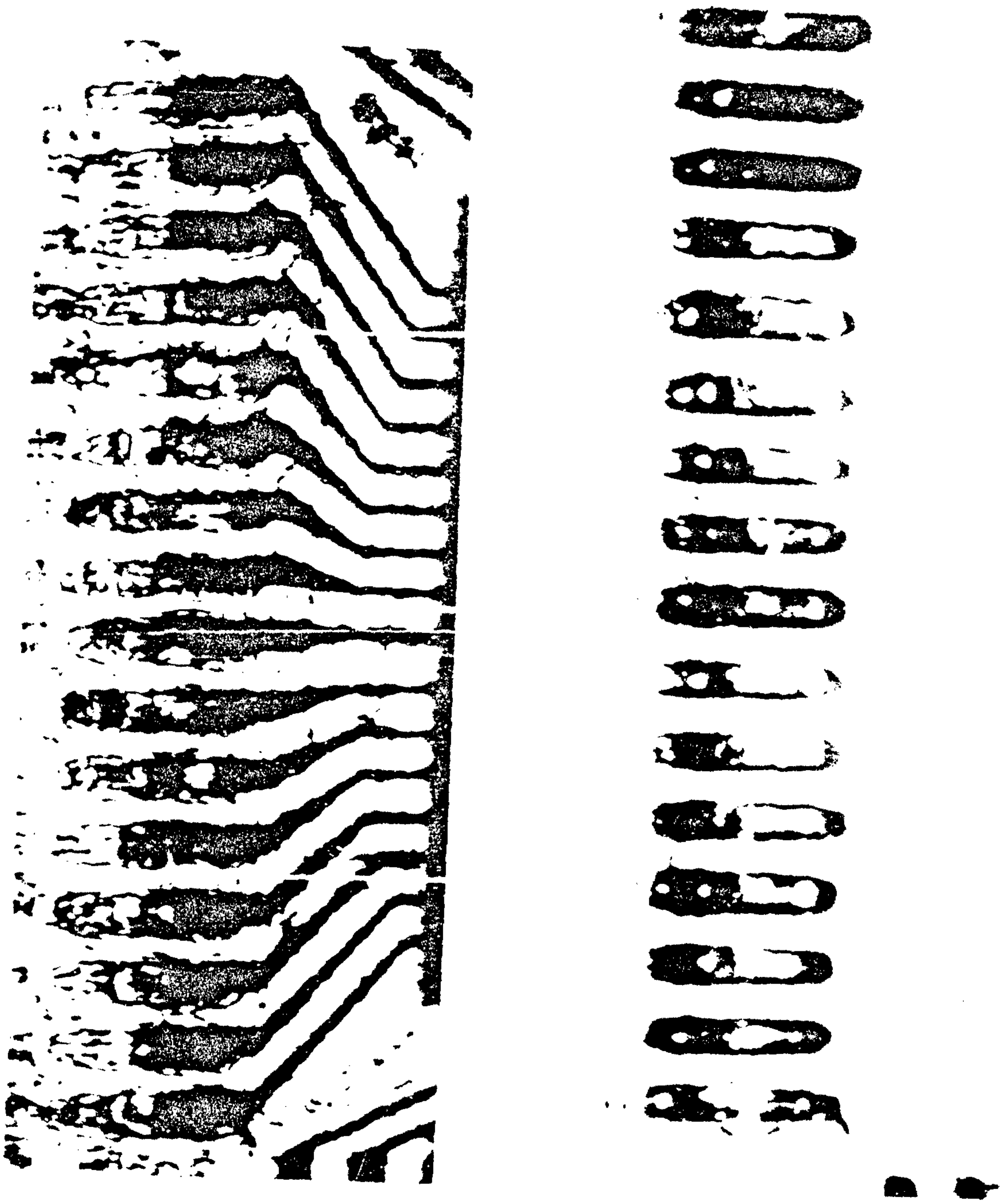


Figure 4.42 SLAM (100 MHz) and corresponding optical images of OLBs on OLB16-2, pins 49-64.

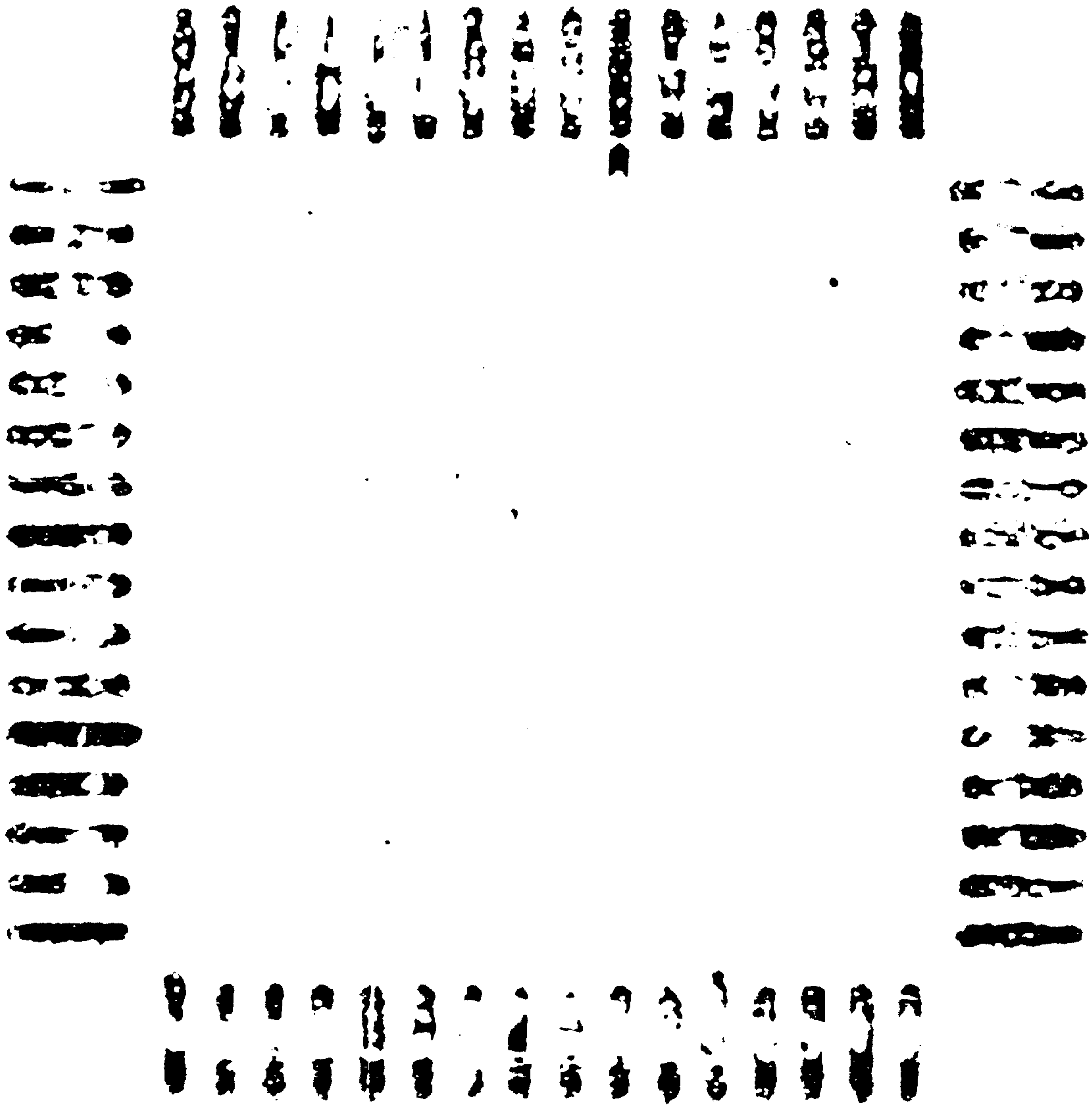


Figure 4.43   Photomicrograph of OLB38-5.

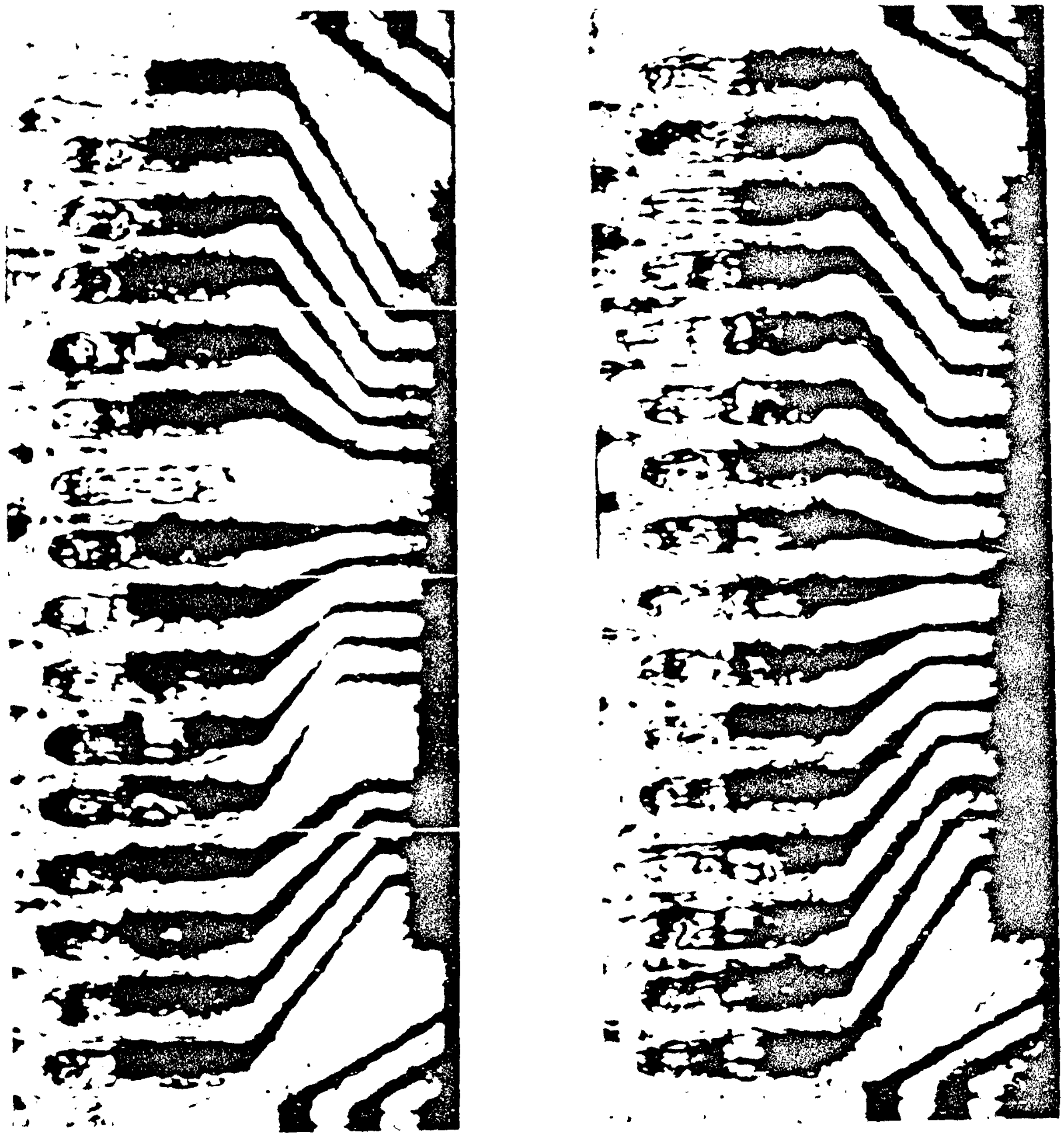


Figure 4.44 SLAM (100 MHz) images of OLBs on OLB38-5, pins 1-32.

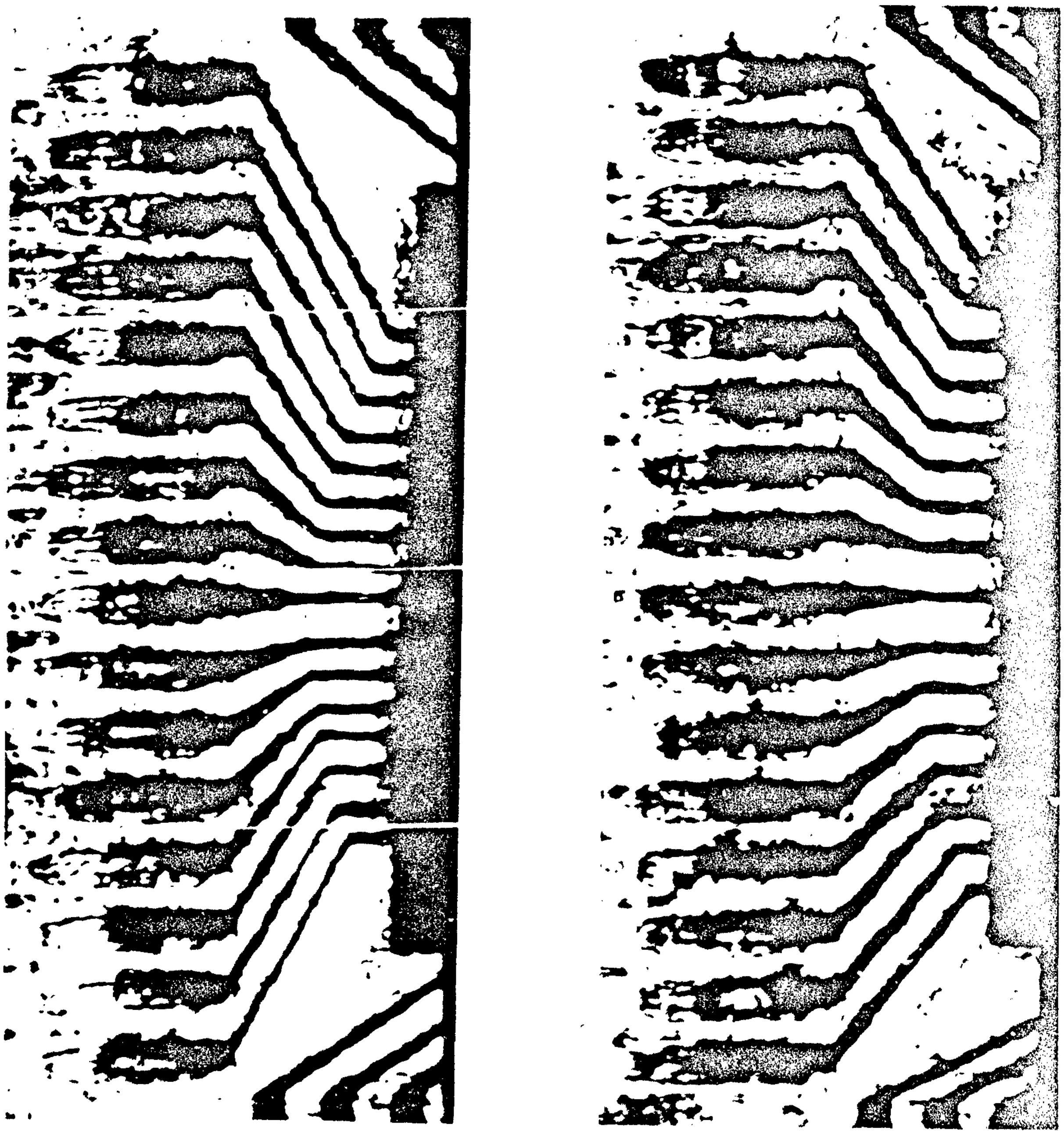


Figure 4.45 SLAM (100 MHz) images of OLBs on OLB38-5, pins 33-64. Note fiber of foreign material bridging pins 52-56 within the bonds.

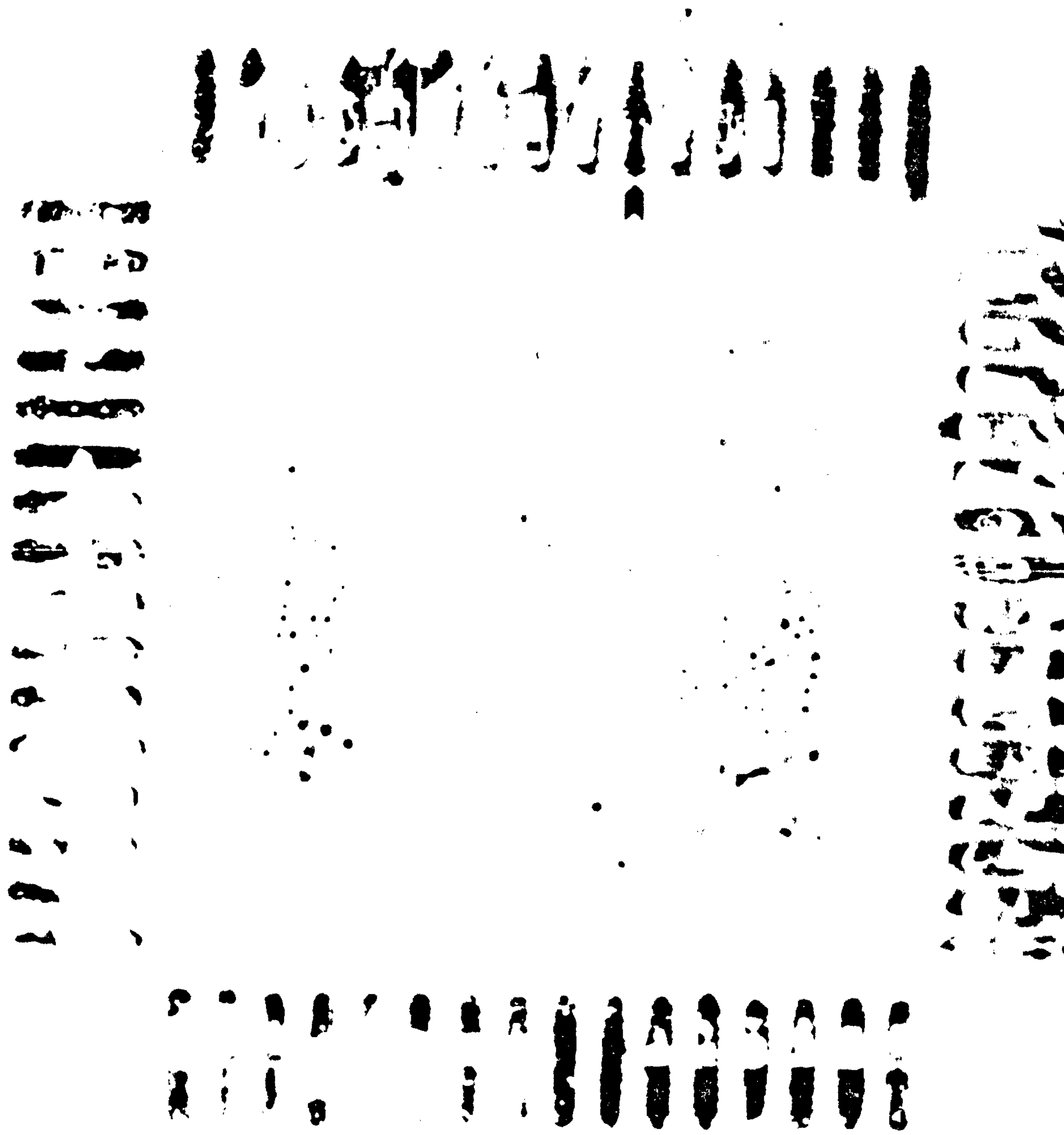


Figure 4.46 Photomicrograph of OLB35-4 after pull testing to reveal the bond sites.

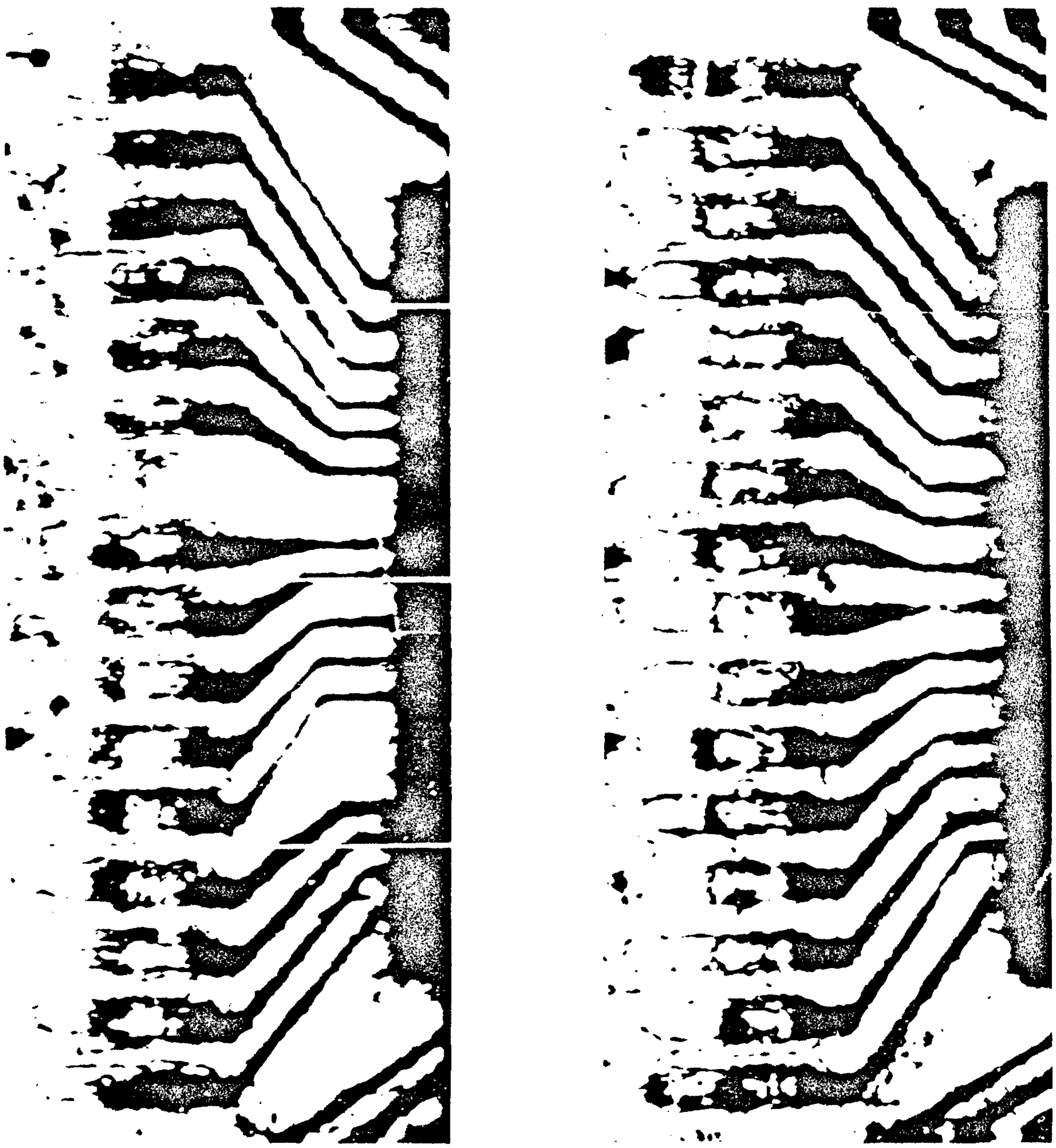


Figure 4.47 SLAM (100 MHz) images of OLBs on OLB35-4. pins 1-32.

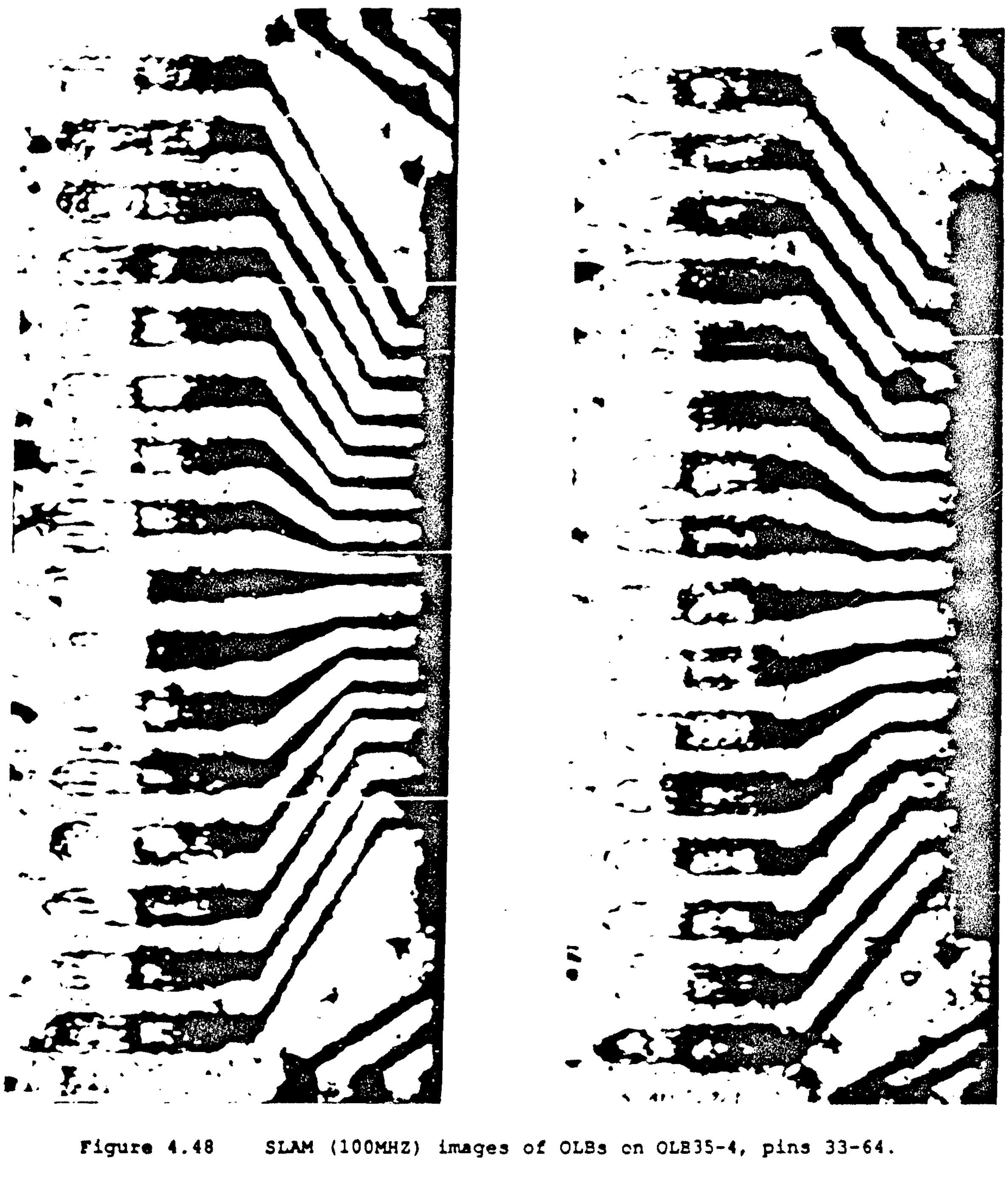


Figure 4.48 SLAM (100MHZ) images of OLBs on OLB35-4, pins 33-64.

For OLB38-5 and OLB35-4, depicted above, area fractions were determined by the more routine methods of photographic inspection using a grid-square counting proceedure to obviate the occurrence of any artifacts. The following graph shows the good degree of correspondence. Note that, unlike the pull test, optical metallography did not show a saturation effect (due to the effect of progressive peeling in the pull test).

The results obtained by the manual gathering of bond area fraction likewise show a linear relationship, without saturation of either optical post-pull bond percent or SLAM pre-pull acoustic bond percent values with respect to each other as the other grows to large values. These two methods thus appear to be quite acceptable linear metrics of each other. If it is accepted that the results of optical metallographic inspectrion are a trustable indication of bond integrity, then it follows that SLAM evaluation is also a trustable indication. The degree of scatrter in the manually prepared optical post-pull bond area graph is lower because of the removal or reduction of the artifact caused by the intruding reflective areas. As other artifacts are better understood (such as by acquiring the capability of discriminating in the optical evaluation between the grainy texture of a forcefully ruptured bond and the graininess of a cold solder joint), scatter in such a graph is anticipated to become further reduced, showing SLAM as a highly trustworthy indicator of bond area percentage and bond integrity.

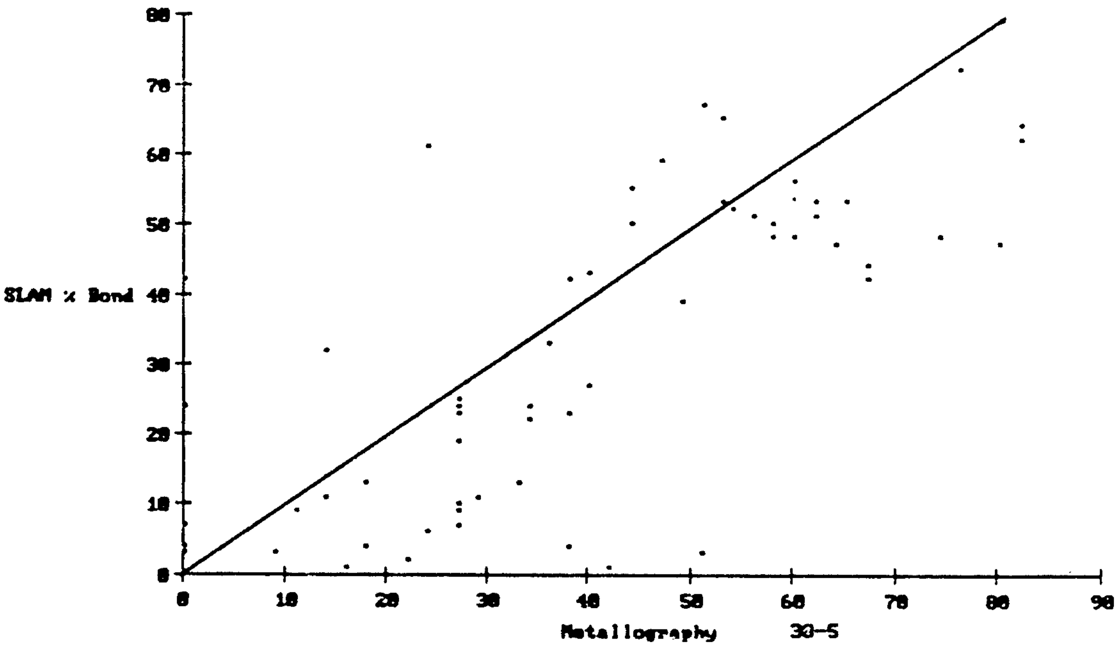


Figure 4.49 Sample OLB38-5 plot of bond area as determined by SLAM vs. optical metallographical area as determined by manual graphical methods instead of by image analyzer. The solid line shows the theoretical equality of the two measurement techniques in the absence of sample damage and measurement error.

POST SCRIPT TO SECTION IV: MATHEMATICAL METHODS

When appraising data according to some property that does not need absolute values, but is ratiometric, the data is often found to be in families which differ categorically; as an example, some of the sample pieces were bonded under near optimum conditions, and offer high values of both pull test strengths and SLAM bond percentages, while others are poorly conditioned in bonding (have a metallury yielding values on a lower scale). A direct averaging between the elements of the differing families is not possible, being tantamount to "adding apples and oranges". Normalization is used to overcome this difficulty. The data points within each family are scaled to some more universal scale. A typical method is to normalize the elements of a family as a fraction of their largest included member. After this proceedure, families may be treated homogenously for those operations in which absolute values are not required.

Sorting is done principally to keep intrinsically different groups of data apart. As an example, the inner lead bonds (ILB) and the outer lead bonds (OLB) differ in a number of important ways: bond area, method of pull testing, and the appearance in one (ILB) of a very pronounced corner effect. It therefore was important to keep these groups separate in order that information inherent in their data not remain hidden, or be further confused, by dilution due to averaging. The same is true of the difference between those bonds pulled by Sonoscan and those pulled by GTE; for whatever reasons, the results obtained appear, on the average, significantly different between themselves. Although sorting was performed, analysis was also done in most cases on each composite (non-sorted) group.

Averaging is used, most obviously, to obtain a view of a trend in the midst of scattered data. A special type of averaging referred to as "smoothing" is also in use in parts of this present analysis. By averaging not simply the members within a given range, but also including an amount of influence from neighboring ranges, a graph becomes literally smoother. The effect is as if a larger number of data points were available, thereby reducing jitter in the plot of the data due to the modest number of data sets included, making overall trends (those with a slower spatial frequency) more distinguishable. If a cyclic pattern is present this smoothing effect can be employed to extend over one half cycle of the period, effectively subtracting that spatial frequency from the graph. It is possible to remove the cyclic pattern in order to perceive whether other trends exist. In this way it is a somewhat less elegant but also less computationally burdensome replacement for a one dimensional Fourier transform and deconvolution. When graphing the value of SLAM bond percentage and/or pull test values against the sixty four lead positions, the use of smoothing over one or two neighboring positions serves merely to reduce the amount of jitter visible in the curve due to the small population; thus it serves only a cosmetic function. In the Appendices, curves are available with and without this smoothing, and also superimposed to demonstrate their essential equivalence. However, when the smoothing effect is used up to eighth-ranked neighboring relationship, any periodic effect which occurs at corners-versus-sides of the

die is nulled, since there are sixteen positions per edge. The periodic valleys and peaks counteract each other, but periodicities at other spatial frequencies are not so affected. The "corner effect" frequency is thereby masked, and any other periodic relationships emerge as more distinguishable. The choice of eighth-ranked neighbor is due to the fact that the period of the effect is sixteen, as this many positions exist between corners, thereby making the half-period to be eight positions in length.

Plotting the composite information of a cluster of many samples on the same graph, against the lead position numbers, requires both a normalization, and then the process of averaging. For ex-ample, the following greatly reduced data set can be considered:

Two samples (artificial; for example purposes only) are examined. Both sample Alpha and sample Beta have eight "positions", and each has a single column of pull test data associated with those positions.

	Pull Test RAW DATA	
Position	Alpha	Beta
1	39.8	14.1
2	80.2	24.7
3	98.7	36.4
4	121.7	38.2
5	109.9	40.6
6	109.1	32.9
7	74.5	26.7
8	42.3	13.3

It is desired to determine what the average effect of position is over both data sets. However, the two parts come from different "pedigrees", and it would be meaningless to average together their absolute values, especially noting the obvious disparity of scale, when what are important are actually the ratios. Therefore, each is normalized to its highest in-sample value. This means that in the case of Alpha, the 121.7 value becomes 1.000, and that in Beta the 40.6 value becomes 1.000, and that all other values are scaled proportionately within that sample. The normalized table becomes:

	Pull Test NORMALIZED DATA		
Position	Alpha	Beta	Avg.
1	.327	.347	.3370
2	.659	.608	.6335
3	.811	.897	.8540
4	1.000	.941	.9705
5	.903	1.000	.9515
6	.896	.810	.8530
7	.612	.658	.6390
8	.348	.328	.3380

The last column is the average of the Alpha and Beta values, which becomes possible to obtain in a fair manner proportionate to their different intrinsic scale because of the earlier normalization.

The average value obtained can now be plotted against the position number, to obtain a graph depicting the effect of position on the value. This method can be extended to any number of samples of various pedigrees, by performing normalization prior to taking the average. This is the method used to depict the corner effects in the various sample sets.

Two other data processing schemes were used in comparing SLAM bond percentage with pull test values:

1) Finding the limiting ratio of bonds which met or exceeded various benchmark pull strengths over the range of SLAM bond percentages;

2) Finding the absolute population-dictated probability of bonds with a given SLAM bond percentage meeting or exceeding various benchmark pull strengths.

The first scheme tallies successes meeting the benchmark whether or not the SLAM criterion is met, even if missed only marginally. It therefore is loaded by cases of "excess strength" (i.e. cases where pull strength seemed disproportionately high with respect to SLAM data. These curves are therefore a limiting case; they would be the boundaries that the real probabilities would approach if no departure from a linear realtionship or data scatter existed. The utility of these curves is marginal; they are included within the appendix as a matter of interest, but are not dealt with further here because they are unrealistically optimistic in favor of SLAM.

The second scheme is of more immediate utility. In a similar way to the first scheme, successes at meeting the pull strength bench marks are tallied for successive zones along the SLAM bond axis. However, "excess strength" cases (those outside the immediate SLAM zone) are not tallied, and therefore the ratio of those meeting or exceeding the benchmark within a zone, versus the total number of all bonds within that zone, becomes the true absolute probability, (expressible as a percentage) of a bond with some given SLAM bond% being able to meet a given pull test bench mark. Because of the strong disparities inherent in the pull test (detailed discussion in the appendices), this graph is actually conservative (pessimistic) in large measure. Nonetheless, it substantiates that SLAM evaluation can be used to predict minimum pull strengths, although actual bond strength would be higher if the lead were to be pulled in a manner that did not lower the value by the "corner effect".

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are derived from assessment of the data and experience gained in this study.

A. Concerning TAB Device

1) Geometry

The jog or dog-leg in beam leads due to the flare-out of the lead pattern between inner lead bond (ILB) and outer lead bond (OLB) positions influences the utility of current pull test methods; however, this effect is eliminated or substantially mollified by the presence of an inner polyimide guard ring as encountered in one set of samples (the ILB region of the MESA samples).

2) Metallurgy

Metallurgical considerations weigh heavily on the absolute intrinsic strength of the bonds. The highest intrinsic strengths encountered in this study were those possessed by the gold-gold thermocompression bonds, followed closely by the gold-tin eutectic. The number of samples of these types which were included was small, as these were not the principle objects of the study. However, they serve to illustrate the importance of the metallurgical element, being at least two or three times the strength of the solder bonds. Further, the specific metallurgy of the solder type bonds is substantially different between the OLB and ILB sites, owing both to the different alloys used there, and the different time, pressure, and temperature conditions used in bonding. Overall, the OLB sites achieved higher values of pull strength. Yet, considering their substantially greater size, they are intrinsically weaker on the basis of strength per absolute area. Moreover, both ILBs and OLBs produced under different (and often very non-ideal) bonding conditions rendered strength values of greatly varying range, as if completely different alloys were employed. Although it is not inconceivable that the chemical nature of the alloy might actually be altered by processes such as leaching and selective crystallization, the principle cause of the difference in properties almost certainly lies in their microcrystalline structure caused by the factors of temperature, pressure and dwell time at bonding. It is therefore important to control these factors in order to obtain known metallurgical strength of the bond substance itself if evaluation of bond area is to be fully meaningful.

B. Concerning Pull Test Methods

1) Peel Test Character

It has been shown that the pull tests as conducted in this study are "peel tests", and rely on a progressive rupturing of the bond, wherein the strength of the bond is seen to be only the peak strength of the widest zone to rupture. Because of this, the geometry of the bond area becomes important with respect to the direction of attack; the highest strengths for a given bond will be obtained when the rupture occurs broadside to the bonds' longest dimension.

2) Vertical Angle

Vertical angle of attack during the pull test is important in at least two ways:

a) Resolved Vector

At a lateral distance from the bond, a pull by hook or other equivalent method although locally vertical at the point of pull is diagonalized by the constraint of the lead. The resolved vertical vector at the bond itself can be greatly lessened. Thus, the applied force at the point of pull may need to increase to substantial values to cause rupture thereby giving higher values than justifiably expected from a straight vertical pull. As the lateral distance decreases, this trigonometric factor also decreases, until it vanishes at a pure vertical pull.

b) Bend Radius

More so than the strictly trigonometric effect, the bend radius of the beam had at its insertion into the bond area changes with the angle of applied pull force. At the fully vertical direction, the acuity of the bend is greatest, and therefore the concentration of rupturing force in the bond substance is greatest. This greatly accentuates the peel test character by narrowing the rupture zone and thus lowering the apparent pull force.

3) Lead Curling-Torque

When beam leads are possessed of a jog or dog-leg, standard pull test methods cause a curling of the lead, with increased exacerbation of the lead radius acuity, thereby further augmenting the peel test character and lowering further the apparent strength of the bond, even though it may be intrinsically as strong as any other bond. This has been referred to as the "corner effect" since dog-legging of the leads is severest at the die corners.

4) Hook Geometry

The saddle-shaped inner curve of the hooks commonly used can potentially augment or occasionally reduce the degree of curling of the rectangularly shaped lead, both in the presence of corner-effect dog-legging of the lead, and otherwise, dependent upon how the beam lead is ensconced in it, and upon frictional considerations. This, combined with frictional considerations that may allow variation in distance of hook from die (or substrate), provides an additional randomizing factor into the measurement of yield strength by means of the pull test.

5) Conclusion

In conclusion, the pull test as formerly conducted on other types of wire bonds is of limited value when applied to TAB devices. A large fraction of this can be attributed to the inappropriateness of the specific tooling; this loss can be

recovered presumably by alteration of fixturing. Other factors, however, are intrinsic in the TAB bond nature itself; the planar nature of the bond geometry leading to a substantial peel character, and the presence of dog-legged beam lead geometry causing a curl in an otherwise flat lead, and resulting concentration of force. The scale of the instruments themselves also provoke difficulty and can cause incidental damage when applied to devices of this minute a scale and degree of density.

C. Concerning Optical Metallographic Inspection

1) Absolute Bond Area

Whereas the use of pull testing presumes to be an absolute index of strength, it remains an index of perceived strength under specific conditions and directions of applied force, and encumbered by practical effects and randomizing factors. Optical metallographic examination on the other hand can yield data on the full areal aspect of bond geometry. Although the additional refinement of deducing specific strengths from microcrystalline examination was not performed in this study, the combination of this with the data of optically obtained bond area fraction would produce as full a bond characterization as is generally practical. Lacking this second layer of information, optical metallography can only characterize the bonds subject to a trust of the specific metallurgical strength or toughness of the bond material.

2) Visible Texture

Two conditions may lead to the textured scattering of light normally taken as defining the area of rupture in an optical evaluation. One is such a ruptured zone itself, and the other is a grainy structure microcrystalline caused by rapid freezing of free-standing solder, as found in cold solder joints. These are distinguishable by careful scrutiny, but easily confused in casual inspection. It is possible that they can co-occur, perhaps with an annulus of grainy crystal surrounding a core of texture caused by rupture. Co-occurrence was not studied or detected in this study, and might require SEM for verification. However, distinct occurrences of each have been seen.

3) Spurious Response

Automated methods for determining the post-pull bond area by optical metallography are also potentially deceived by the presence, in the analysis window, of such misleading features as shiny areas of solder at such angles as to cause bright areas that are not part of a bond residue.

4) Manual Assessment

When optical metallographic inspection is performed manually, a perceptive operator can discriminate between misleading features such as discussed above, and with careful scrutiny can also discriminate between the texture of a ruptured bond residue, and the texture of a grainy surface due to rapid

crystallization not participating in bond formation. This latter discrimination is difficult and tedious at the lightings and magnifications that were available in this study. However, having performed these discriminations, a true prior bond area can be determined by manual optical metallography. When combined with a knowledge of intrinsic metallurgical strength of the bond substance, an essentially absolute value of bond strength could theoretically be obtained. A prediction of how this would relate to pull test strength would necessarily involve consideration of other geometric and mechanical elements related to the beam lead and the pull test methodology itself.

D. Concerning SLAM

1) Clear Visualization of Bond Area

SLAM consistently and readily shows images of the bond area as bright areas as displayed in the standard image format. The brightness is symptomatic of high transmission of acoustic energy through the bonded sites, which occurs because of material integrity. In places where there is no bond integrity, any acoustic energy must transit through alternate media (bond pad, coupling fluid, and then beam lead) before it can emerge at the other side. At each interface, much energy is returned because of impedance mismatch, and also scattered by refraction. Such areas are profoundly darker. When transmitting through sufficiently grainy material, much energy is scattered. These areas are very substantially darkened.

2) Corner Effect Disparity

Although extensive variation in pull test values cause scatter in the plotting of SLAM vs pull test data, these variations have been explored, and accounted for. When graphed in a method which betrays the nature of these variations, the close correspondence of SLAM analysis with bond strength becomes obvious. The most pronounced scattering factor is the "corner effect" in the pull test. When the spatial frequency of this corner effect is suppressed, the curve of SLAM averages tracks the pull test averages very well.

3) SLAM and Metallographic Correlate

An even better correspondence exists between SLAM and optical metallography. The sizes and shapes of bond areas within bonded regions viewed by SLAM agree to a high degree with the same sizes and shapes seen by optical metallography in the residues of pulled bonds. Neither optical metallography nor SLAM determine the intrinsic composition of the bond substance. If this intrinsic metallurgical strength is determined by independent means, both optical metallography (after destruction of the bond), and SLAM (nondestructive) give equivalent assessments of bond strength.

APPENDIX "A"

The SLAM Bond% and Pull Test DATA

For purposes of listing, the data presented here are broken into three groups:

GROUP 1: ILB Samples (solder TAB)
GROUP 2: OLB Samples (solder TAB)
GROUP 3: MESA ILB (AuAu & AuSn TAB)

The samples are listed alpha-numerically within each of the three sub-sections which follow.

The members of each group may be further sub-classified according to the following breakdowns:

GROUP 1:
By party performing pull-test: Sonoscan or GTE
By conditions under which gang bonding was performed:

	Pres	Temp	Time
high	7	390	5.9
med	3	340	4.9
low	1	200	3.9

GROUP 2:
By party performing pull-test: Sonoscan or GTE
By conditions under which gang bonding was performed:

	Pres	Temp	Time
high	22	320	3.0
med	11	290	1.5
low	5	260	0.8

GROUP 3:
By metallic species: Au-Au or Au-Sn
By pressure under which gang bonding was performed:
low, med, high (specifics not given)
(Pull tests for these parts all done at Sonoscan)

POS	PRES	TIME	TEMP	SAMPLES INCLUDED			
00	L	L	L		none		
01	L	L	M	59-2	59-3	59-4	61-5
02	L	L	H		none		
03	L	M	L		none		
04	L	M	M	60-2			
05	L	M	H			57-4	
06	L	H	L		none		
07	L	H	M		none		
08	L	H	H		none		
09	M	L	L		none		
10	M	L	M			48-5	
11	M	L	H	53-2		55-5	
12	M	M	L			48-4	48-5
13	M	M	M		none		
14	M	M	H			54-4	
15	M	H	L		none		
16	M	H	M		none		
17	M	H	H			55-5	
18	H	L	L		none		
19	H	L	M			47-5	
20	H	L	H	50-2		66-4	50-5
21	H	M	L		none		
22	H	M	M	49-2		49-4	49-5
23	H	M	H	51-2		51-4	51-5
24	H	H	L			48-4	
25	H	H	M			49-4	49-5
26	H	H	H	52-2		52-4	52-5

NOMINAL VALUES

	Pres	Time	Temp
high	7	5.9	396
mod	5	4.9	348
low	1	3.9	286

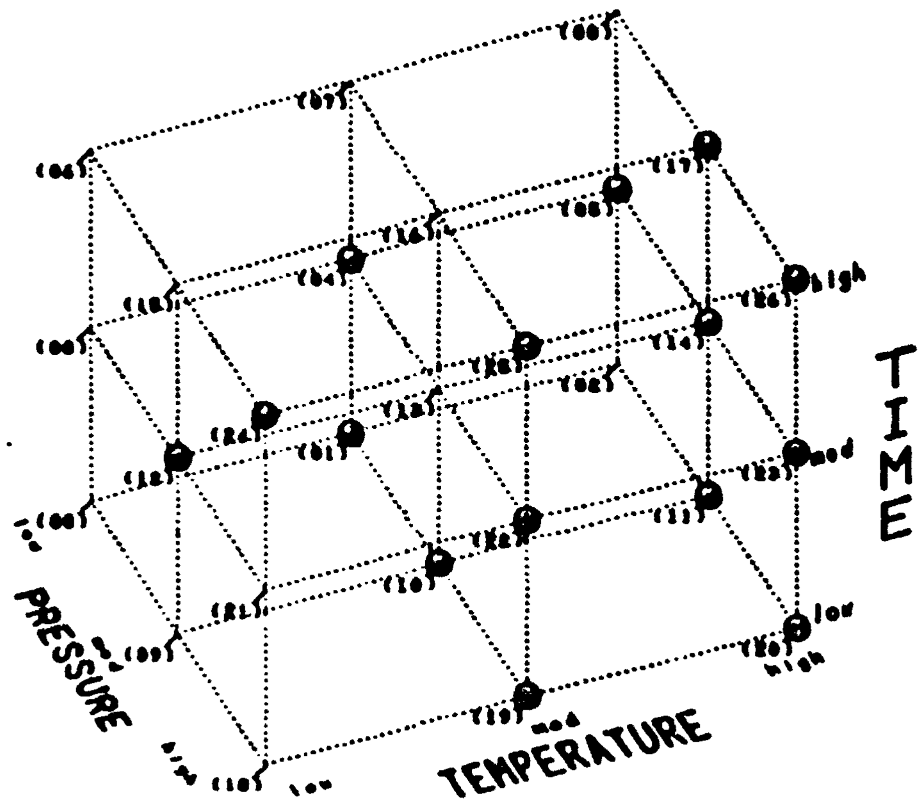


Figure A.1 ILB-xx (Matrix of Bonding Conditions) ILB-xx

POS	PRES	TIME	TEMP	SAMPLES INCLUDED		
00	L	L	h	none		
01	L	L	m	none		
02	L	L	m	none		
03	L	M	h	none		
04	L	M	m		17-8	
05	L	M	m	none		
06	L	M	h	none		
07	L	M	m	14-8		
08	L	M	m	21-8	21-8	
09	M	L	L	none		
10	M	L	m		[illegible]-4	
11	M	L	m	97-8	[illegible]-4	
12	M	M	L	none		
13	M	M	m	[illegible]	[illegible]	
14	M	M	m	[illegible]	[illegible]-4	
15	M	M	h		[illegible]	
16	M	M	m	[illegible]	[illegible]-4	
17	M	M	m	[illegible]	[illegible]-4	88-6
18	M	L	L	none		
19	M	L	m	none		
20	M	L	m	84-8	84-8	
21	M	M	h	none		
22	M	M	m	[illegible]		
23	M	M	m	[illegible]	88-6	
24	M	M	h		[illegible]	
25	M	M	m	89-8	[illegible]	
26	M	M	m	none		

NOMINAL VALUES

	Pres	Time	Temp
high	22	8.0	320
mod	11	1.8	290
low	6	0.6	260

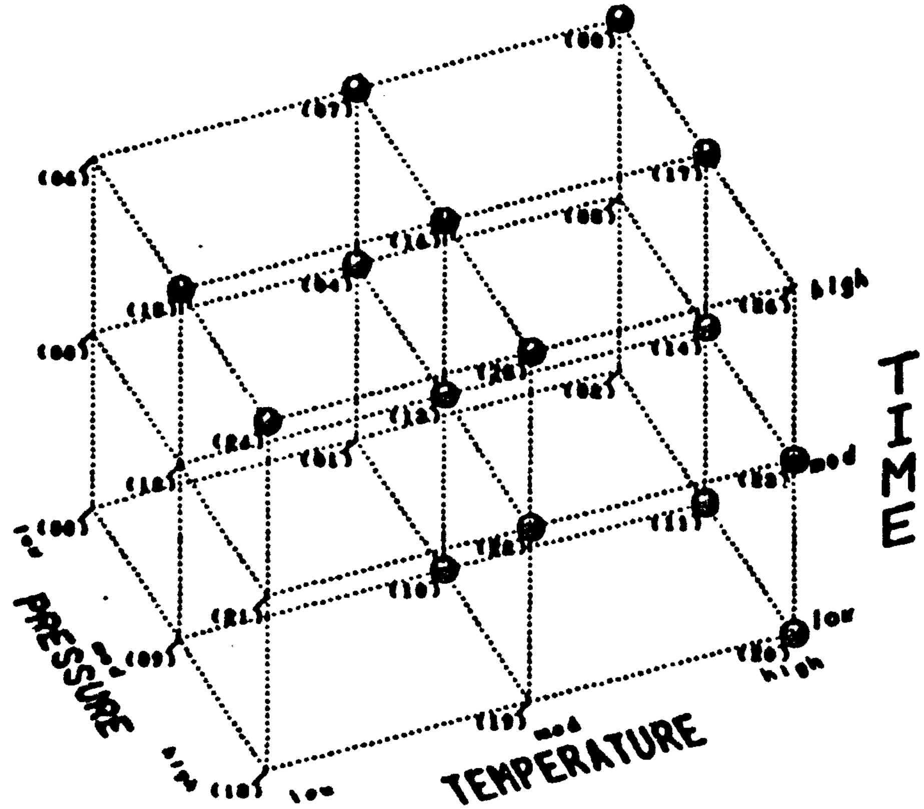


Figure A.2 OLB-xx (Matrix of Bonding Conditions) OLB-xx

Explanation of the Exclusion codes

In the data listing, and the index sheets and text, use is made of a range of codes (0-9) as exclusion codes for data handling. The following is an explanation of how these codes are derived and used.

0) This code implies that the data were not given any special exclusion status, and are never subject to exclusion. Some of these data points are in fact suspect, but those which are not serious disparities are left as code "0". See (1).

1) This code was given when the disparity between SLAM Bond% data and pull test data is severe, especially in the cases where the sample piece had numerous other sites of such high disparity. When the pull-test operator marked down such other cases of high disparity with remarks which explained the disparity, then other codes (see below) were given. However, when adjacent sites were not given the benefit of operator observation, yet express similar great disparity, they then receive code "1". The presence of this code DOES NOT mean that the data were excluded, but rather this code is simply a "footnote" that such data point is quite suspect, and thus "ought" to be excluded.

2) This code acts to exclude data points which are phantom sites. Specifically, in the solder TAB samples, position #10 is an aboriginally vacant position, and thus bears no real data in spite of the zero values recorded as place holders.

3) Pull tester did not reset. Apparently, an occasional equipment failure, where the pull test machinery did not recover to a zero state, or to a triggerable state, from the prior activation. Noted in the original data as a remark to the effect "did not reset".

4) Known prior damage/handling. The test operator could not perform a pull test because of a damaged condition at this site, noted prior to or during the attempt to perform the test with a remark such as "beam fell off" or "damaged".

5) Pull tester did not record. Apparently, an occasional equipment failure, where the pull test machiery did not record a value in spite of the performance of an otherwise normal pull. This seemed to occur most frequently during a few periods of pull-testing by GTE, and is reflected by peak occurence in certain samples. It is not sure, or likely, that the sample itself, however, was a contributing factor. Noted in the original data with a remark to the effect "did not record".

(explanation of exclusion codes, Continued)

6) Unstored/unreadble SLAM. This code occ~~s when the SLAM data were considered by the operator to be invalid. In a few cases, the cause may be a "SLAM did not record" error, meaning that the operator did not correctly place the analysis window, or failed to make a recording. In the majority of cases, however, an air bubble may have clung to the sample site, or grew there because of out-gassing of air previously dissolved in the water. Under the conditions of this test regimen, it was considered to be inappropriate to attempt to brush away the bubble because of the possibility of resultant damage.

7) Solder-bridged leads. The operator found that two or more bonding areas were either contacting, or apparently mutually bonded by extruded solder or other material.

8) Pad-Lift. The operator noted that a pull-test could not be performed because the pad over the silicon die itself had become lifted or partly lifted. In the case of a partial lift, the test was performed anyway. Virtually all of the code "8" sites occured in samples where the bonding pressure or temperature, or both, were "high".

9) Kapton-affected leads. Operator notes "kapton strip connects leads...can't pull" This occured in one sample, OLB37-4, primarily along one edge.

Table A.1 ILB Samples

ILB Samples (solder TAB)

BONDING CONDITIONS: dwell time, temperature, pressure

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	BONDING CONDITIONS: dwell time / temperature / pressure
ILB42-4	84.21	15.21	15.46	7.50	0.72	0.73	1	2	SS	MLM
ILB42-5	95.05	25.03	25.42	6.00	0.88	0.90	1	2	SS	MLM
ILB46-4	96.90	39.17	39.13	6.00	1.80	1.92	3	4	SS	HLH
ILB47-5	89.16	48.47	49.24	47.00	33.45	33.98	1	2	SS	HML
ILB48-3	89.78	45.89	49.33	24.00	12.45	14.38	6	5	GTE	HMM
ILB48-4	92.26	48.59	49.54	46.00	28.84	29.77	1	2	SS	HMM
ILB48-5	88.24	47.65	47.65	45.00	27.58	27.97	2	7	SS	HMM
ILB49-4	84.52	44.09	44.79	45.00	31.20	31.70	1	2	SS	HMH
ILB49-5	88.85	40.05	40.98	44.00	27.61	28.50	1	2	SS	HMH
ILB50-2	97.21	55.77	61.29	44.00	24.41	23.77	9	6	GTE	HHL
ILB50-4	96.59	67.42	68.49	49.00	29.50	29.97	1	2	SS	HHL
ILB50-5	97.21	64.73	65.58	40.00	26.92	27.79	1	2	SS	HHL
ILB51-3	88.54	49.43	50.63	61.00	27.16	28.03	1	2	GTE	HHM
ILB51-4	93.50	56.58	61.16	50.00	32.12	34.85	4	8	SS	HHM
ILB51-5	83.28	50.01	52.15	50.00	37.09	38.70	2	8	SS	HHM
ILB52-3	92.57	51.12	54.82	54.00	25.36	25.90	4	6	GTE	HHH
ILB52-4	81.42	53.55	54.40	50.00	43.03	43.71	1	2	SS	HHH
ILB52-5	96.90	47.69	49.23	55.00	38.75	40.00	1	2	SS	HHH
ILB53-2	100.00	41.41	45.43	27.00	11.92	13.28	6	5	GTE	MHL
ILB53-5	96.28	60.64	61.60	46.00	23.47	23.84	1	2	SS	MHL
ILB54-4	90.09	52.95	53.79	44.00	24.13	24.51	1	2	SS	MHM
ILB55-5	88.85	48.41	49.18	46.00	29.77	30.24	1	2	SS	MHH
ILB57-4	73.99	41.64	42.30	38.00	20.31	20.63	1	2	SS	LHM
ILB59-2	92.57	44.58	48.13	12.00	2.25	7.58	44	5	GTE	LML
ILB59-3	90.40	35.52	36.70	18.00	6.44	9.28	15	5	GTE	LML
ILB59-4	89.47	40.88	41.52	14.00	3.80	3.86	1	2	SS	LML
ILB60-2	95.36	50.19	47.25	13.00	4.17	8.90	33	5	GTE	LMM
ILB61-5	85.45	51.83	52.65	41.00	17.73	18.02	1	2	SS	LML
ILB62-5	80.19	36.46	40.23	41.00	16.73	17.64	4	6	SS	MML

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB42-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: low Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	5.57	0.00	0	33	0.00	0.00	0
2	9.91	0.00	0	34	0.31	0.00	0
3	0.62	0.00	0	35	0.00	0.00	0
4	0.31	0.00	0	36	0.00	0.00	0
5	2.17	0.00	0	37	0.00	0.00	0
6	0.00	0.00	0	38	0.00	0.00	0
7	0.31	0.00	0	39	0.00	0.00	0
8	0.62	0.00	0	40	0.00	0.00	0
9	1.24	0.00	0	41	22.91	0.00	0
10	0.00	0.00	2	42	0.00	0.00	0
11	11.76	0.00	0	43	0.00	0.00	0
12	11.46	0.00	0	44	0.00	0.00	0
13	0.00	0.00	0	45	28.48	0.00	0
14	0.00	0.00	0	46	40.56	0.00	0
15	0.00	0.00	0	47	10.84	0.00	0
16	0.00	0.00	0	48	27.24	0.00	0
17	0.00	0.00	0	49	2.17	0.00	0
18	0.00	0.00	0	50	38.02	0.00	0
19	0.00	0.00	0	51	33.44	0.00	0
20	0.00	0.00	0	52	37.15	0.00	0
21	0.00	0.00	0	53	70.28	4.00	0
22	3.72	0.00	0	54	71.21	3.00	0
23	0.62	0.00	0	55	84.21	7.00	0
24	0.00	0.00	0	56	41.49	6.50	0
25	3.72	0.00	0	57	65.05	7.50	0
26	0.00	0.00	0	58	80.80	4.50	0
27	1.24	0.00	0	59	68.73	2.50	0
28	0.62	0.00	0	60	47.68	3.00	0
29	0.00	0.00	0	61	35.91	3.00	0
30	3.72	0.00	0	62	57.28	2.50	0
31	0.31	0.00	0	63	50.77	2.50	0
32	0.00	0.00	0	64	1.24	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB42-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: low Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	4.64	0.00	0	33	0.93	2.50	0
2	63.16	0.00	0	34	2.79	3.00	0
3	0.00	0.00	0	35	93.81	3.00	0
4	52.32	0.00	0	36	84.83	4.00	0
5	2.17	0.00	0	37	94.74	4.00	0
6	0.31	0.00	0	38	91.33	0.00	0
7	0.00	0.00	0	39	93.19	6.00	0
8	0.00	0.00	0	40	0.31	6.00	0
9	0.31	0.00	0	41	87.31	4.50	0
10	0.00	0.00	2	42	81.42	3.00	0
11	0.62	0.00	0	43	95.05	3.00	0
12	0.00	0.00	0	44	78.98	3.50	0
13	40.87	0.00	0	45	91.02	3.00	0
14	2.17	0.00	0	46	83.28	3.00	0
15	0.31	0.00	0	47	82.04	0.00	0
16	0.00	0.00	0	48	75.23	0.00	0
17	1.86	0.00	0	49	0.00	0.00	0
18	0.62	0.00	0	50	0.00	0.00	0
19	3.10	0.00	0	51	0.31	0.00	0
20	0.31	0.00	0	52	1.86	0.00	0
21	0.00	0.00	0	53	0.00	0.00	0
22	0.00	0.00	0	54	0.00	0.00	0
23	0.00	0.00	0	55	0.31	0.00	0
24	0.00	0.00	0	56	0.62	0.00	0
25	0.00	0.00	0	57	79.26	2.00	0
26	2.79	0.00	0	58	65.94	3.00	0
27	0.00	0.00	0	59	0.00	0.00	0
28	0.31	0.00	0	60	0.00	0.00	0
29	0.00	0.00	0	61	0.00	0.00	0
30	0.62	0.00	0	62	80.19	3.00	0
31	0.62	0.00	0	63	57.28	0.00	0
32	2.48	0.00	0	64	0.00	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.3 ILB46-4

ILB46-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: low Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	70.80	0.00	4	33	93.19	4.00	0
2	60.99	0.00	0	34	82.97	2.00	0
3	1.24	0.00	0	35	86.69	4.00	0
4	62.23	0.00	0	36	62.54	3.00	0
5	41.49	5.00	0	37	86.38	5.50	0
6	60.99	0.00	0	38	87.62	6.00	0
7	2.17	0.00	0	39	79.26	6.00	0
8	43.34	4.00	0	40	0.00	0.00	0
9	82.66	0.00	0	41	95.36	6.00	0
10	0.00	0.00	2	42	87.93	5.00	0
11	20.43	0.00	0	43	88.85	4.50	0
12	78.64	4.00	0	44	96.90	4.00	0
13	54.80	0.00	4	45	93.81	3.00	0
14	51.70	0.00	0	46	88.85	3.50	0
15	9.60	0.00	0	47	83.90	3.00	0
16	11.46	0.00	0	48	77.09	3.00	0
17	0.00	4.50	0	49	1.55	0.00	0
18	63.47	0.00	0	50	0.62	0.00	0
19	55.73	0.00	0	51	2.48	0.00	0
20	1.86	0.00	0	52	84.83	5.00	0
21	81.73	4.00	0	53	85.76	4.50	0
22	3.10	0.00	0	54	2.48	0.00	0
23	78.02	4.00	0	55	74.92	0.00	4
24	72.76	3.50	0	56	75.54	6.00	0
25	2.17	0.00	0	57	88.54	4.50	0
26	74.30	5.00	0	58	0.00	0.00	0
27	64.09	4.00	0	59	0.00	0.00	0
28	68.42	3.50	0	60	0.62	0.00	0
29	13.93	0.00	0	61	0.00	0.00	0
30	87.00	3.00	0	62	1.24	0.00	0
31	78.95	0.00	4	63	53.87	3.00	0
32	71.52	3.00	0	64	3.41	0.00	0

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.4 ILB47-5

ILB47-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	42.11	17.00	0	33	42.41	30.00	0
2	41.80	24.00	0	34	34.37	32.00	0
3	35.60	25.00	0	35	29.10	35.00	0
4	31.27	38.00	0	36	32.82	40.00	0
5	51.39	28.00	0	37	67.49	40.00	0
6	44.27	44.00	0	38	42.11	38.00	0
7	54.80	40.00	0	39	57.28	44.00	0
8	54.49	44.00	0	40	48.61	35.00	0
9	57.89	46.00	0	41	52.32	45.00	0
10	0.00	0.00	2	42	54.18	42.00	0
11	76.16	47.00	0	43	63.78	34.00	0
12	61.30	45.00	0	44	63.47	41.00	0
13	46.75	43.00	0	45	62.85	37.00	0
14	31.58	34.00	0	46	55.73	26.00	0
15	39.23	41.00	0	47	45.51	19.00	0
16	36.84	43.00	0	48	51.08	15.00	0
17	52.32	15.00	0	49	55.73	33.00	0
18	40.56	15.00	0	50	68.11	40.00	0
19	53.25	25.00	0	51	57.89	42.00	0
20	29.10	23.00	0	52	63.16	41.00	0
21	46.13	37.00	0	53	89.16	39.00	0
22	65.63	35.00	0	54	65.63	25.00	0
23	63.47	39.00	0	55	60.99	33.00	0
24	58.20	42.00	0	56	33.44	46.00	0
25	81.11	44.00	0	57	16.72	43.00	0
26	73.37	38.00	0	58	22.91	35.00	0
27	87.62	41.00	0	59	24.15	33.00	0
28	58.20	42.00	0	60	20.43	35.00	0
29	43.96	43.00	0	61	27.86	22.00	0
30	49.85	41.00	0	62	23.84	19.00	0
31	34.37	18.00	0	63	43.34	19.00	0
32	40.25	15.00	0	64	34.06	11.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.5 ILB48-3

ILB48-3
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	75.54	19.00	0	33	25.70	12.00	0
2	48.61	24.00	0	34	55.70	13.00	0
3	17.96	18.00	0	35	61.92	11.00	0
4	27.24	22.00	0	36	46.13	15.00	0
5	55.11	0.00	4	37	52.94	13.00	0
6	53.25	19.00	0	38	58.82	14.00	0
7	37.15	23.00	0	39	89.78	18.00	0
8	26.01	21.00	0	40	69.04	21.00	0
9	48.61	22.00	0	41	85.76	17.00	0
10	0.00	0.00	2	42	71.52	18.00	0
11	49.85	14.00	0	43	62.85	15.00	0
12	13.00	12.00	0	44	41.80	8.00	0
13	38.70	8.00	0	45	59.75	10.00	0
14	36.84	0.00	5	46	57.89	12.00	0
15	16.10	0.00	5	47	40.87	6.00	0
16	25.39	0.00	5	48	71.52	0.00	5
17	77.71	12.00	0	49	53.25	11.00	0
18	69.04	17.00	0	50	41.18	12.00	0
19	56.35	15.00	0	51	30.34	13.00	0
20	23.22	23.00	0	52	0.00	11.00	6
21	60.06	21.00	0	53	56.66	11.00	0
22	37.46	14.00	0	54	37.77	16.00	0
23	44.24	18.00	0	55	22.91	13.00	0
24	24.77	14.00	0	56	0.00	14.00	6
25	35.60	11.00	0	57	22.29	10.00	0
26	49.85	19.00	0	58	57.28	18.00	0
27	57.28	13.00	0	59	45.82	11.00	0
28	39.32	10.00	0	60	16.72	8.00	0
29	72.76	8.00	0	61	70.90	10.00	0
30	70.90	6.00	0	62	73.37	10.00	0
31	73.68	0.00	5	63	51.08	13.00	0
32	48.61	0.00	5	64	5.26	10.00	6

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.6 ILB48-4

ILB48-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	50.15	38.00	0	33	66.87	27.00	0
2	56.97	26.00	0	34	86.07	23.00	0
3	37.77	30.00	0	35	78.33	31.00	0
4	33.44	35.00	0	36	53.25	34.00	0
5	50.15	25.00	0	37	61.61	37.00	0
6	55.42	29.00	0	38	73.37	38.00	0
7	68.73	29.00	0	39	61.30	46.00	0
8	73.68	41.00	0	40	42.41	46.00	0
9	36.84	43.00	0	41	66.25	45.00	0
10	0.00	0.00	2	42	74.61	36.00	0
11	61.30	40.00	0	43	38.08	39.00	0
12	44.58	36.00	0	44	62.85	29.00	0
13	21.67	27.00	0	45	57.89	29.00	0
14	61.61	15.00	0	46	87.00	18.00	0
15	49.23	16.00	0	47	58.20	20.00	0
16	36.53	24.00	0	48	36.22	13.00	0
17	17.32	18.00	0	49	16.10	13.00	0
18	42.72	34.00	0	50	49.85	20.00	0
19	20.12	22.00	0	51	46.44	22.00	0
20	28.48	19.00	0	52	38.08	28.00	0
21	26.01	20.00	0	53	53.87	41.00	0
22	55.42	26.00	0	54	92.26	37.00	0
23	36.22	23.00	0	55	33.44	43.00	0
24	21.98	19.00	0	56	47.37	45.00	0
25	20.74	26.00	0	57	47.37	39.00	0
26	43.96	25.00	0	58	79.57	45.00	0
27	40.87	20.00	0	59	48.92	37.00	0
28	44.27	22.00	0	60	59.75	32.00	0
29	29.72	18.00	0	61	48.61	40.00	0
30	49.23	24.00	0	62	63.47	36.00	0
31	39.32	10.00	0	63	42.72	42.00	0
32	38.08	0.00	3	64	44.89	35.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB48-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	63.78	19.00	0	33	71.21	19.00	0
2	20.74	22.00	0	34	55.11	28.00	0
3	43.65	28.00	0	35	58.51	41.00	0
4	32.51	32.00	0	36	45.20	27.00	0
5	35.29	18.00	0	37	52.32	30.00	0
6	42.41	24.00	0	38	71.21	42.00	7
7	48.92	32.00	0	39	70.59	45.00	7
8	33.44	35.00	0	40	56.04	45.00	0
9	51.39	39.00	0	41	56.66	45.00	0
10	0.00	0.00	2	42	88.24	40.00	0
11	57.28	42.00	0	43	63.47	28.00	0
12	63.16	27.00	0	44	53.56	26.00	0
13	25.39	25.00	0	45	57.89	32.00	0
14	36.53	18.00	0	46	44.89	16.00	0
15	25.39	13.00	0	47	17.65	20.00	0
16	30.03	13.00	0	48	32.51	18.00	0
17	63.78	20.00	0	49	47.06	17.00	0
18	60.06	24.00	0	50	54.49	17.00	0
19	44.89	25.00	0	51	50.77	25.00	0
20	35.91	23.00	0	52	55.11	25.00	0
21	31.58	28.00	0	53	78.02	31.00	0
22	52.94	33.00	0	54	72.45	39.00	0
23	42.72	35.00	0	55	56.66	40.00	0
24	41.18	38.00	0	56	35.29	41.00	0
25	43.96	38.00	0	57	32.51	38.00	0
26	41.18	31.00	0	58	48.61	0.00	8
27	31.58	22.00	0	59	47.37	31.00	0
28	39.01	23.00	0	60	39.63	29.00	0
29	50.77	22.00	0	61	54.49	37.00	0
30	56.66	21.00	0	62	31.59	26.00	0
31	52.94	19.00	0	63	63.16	31.00	0
32	34.06	9.00	0	64	54.18	38.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.8 ILB49-4

ILB49-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	57.89	21.00	0	33	49.23	38.00	0
2	66.87	23.00	0	34	71.52	41.00	0
3	59.44	27.00	0	35	51.39	38.00	0
4	40.87	35.00	0	36	31.27	42.00	0
5	60.06	24.00	0	37	47.68	33.00	0
6	72.76	33.00	0	38	75.23	40.00	0
7	63.16	34.00	0	39	50.46	45.00	0
8	54.80	45.00	0	40	55.11	45.00	0
9	55.11	44.00	0	41	55.11	45.00	0
10	0.00	0.00	2	42	64.71	40.00	0
11	62.85	42.00	0	43	51.08	42.00	0
12	60.06	42.00	0	44	54.18	35.00	0
13	48.61	38.00	0	45	63.78	32.00	0
14	52.94	19.00	0	46	52.32	28.00	0
15	45.51	18.00	0	47	36.22	29.00	0
16	41.18	18.00	0	48	39.32	22.00	0
17	14.55	18.00	0	49	75.23	28.00	0
18	28.48	9.00	0	50	74.61	27.00	0
19	0.93	12.00	0	51	49.54	38.00	0
20	19.50	17.00	0	52	61.30	33.00	0
21	14.86	18.00	0	53	51.70	36.00	0
22	41.80	21.00	0	54	46.75	41.00	0
23	5.26	25.00	0	55	43.96	38.00	0
24	26.93	37.00	0	56	50.15	43.00	0
25	29.10	34.00	0	57	52.01	40.00	0
26	14.86	37.00	0	58	43.65	44.00	0
27	17.36	24.00	0	59	65.33	37.00	0
28	22.60	27.00	0	60	31.48	27.00	0
29	7.43	29.00	0	61	67.00	29.00	0
30	18.89	44.00	0	62	84.52	32.00	0
31	1.86	18.00	0	63	44.58	28.00	0
32	10.84	13.00	0	64	40.87	25.00	0

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.9 ILB49-5

ILB49-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	39.32	10.00	0
2	33.34	13.00	0
3	32.20	14.00	0
4	23.22	12.00	0
5	13.62	21.00	0
6	22.29	0.00	4
7	35.91	15.00	0
8	29.10	19.00	0
9	13.93	16.00	0
10	0.00	0.00	2
11	11.76	21.00	0
12	13.62	14.00	0
13	36.22	14.00	0
14	32.51	11.00	0
15	34.98	10.00	0
16	17.34	8.00	0
17	48.30	37.00	0
18	50.46	31.00	0
19	43.03	28.00	0
20	42.72	40.00	0
21	34.67	39.00	0
22	28.17	41.00	0
23	22.60	41.00	0
24	19.81	40.00	0
25	18.58	38.00	0
26	23.22	37.00	0
27	36.22	27.00	0
28	23.53	30.00	0
29	35.91	31.00	0
30	32.20	33.00	0
31	24.15	31.00	0
32	30.34	24.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	24.77	10.00	0
34	37.15	15.00	0
35	28.48	18.00	0
36	30.34	18.00	0
37	28.79	23.00	0
38	37.15	32.00	0
39	37.15	40.00	0
40	34.37	38.00	0
41	21.05	33.00	0
42	53.25	33.00	0
43	30.65	21.00	0
44	63.47	22.00	0
45	32.20	11.00	0
46	39.63	15.00	0
47	29.10	24.00	0
48	54.80	15.00	0
49	69.35	31.00	0
50	86.38	36.00	0
51	54.80	40.00	0
52	63.16	41.00	0
53	65.95	43.00	0
54	88.85	44.00	0
55	55.73	42.00	0
56	51.08	44.00	0
57	44.58	44.00	0
58	55.11	44.00	0
59	81.42	35.00	0
60	65.02	40.00	0
61	71.21	42.00	0
62	80.50	43.00	0
63	76.78	44.00	0
64	67.49	40.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.10 ILB50-2

ILB50-2
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	53.25	18.00	0	33	73.68	21.00	0
2	91.95	24.00	0	34	66.56	26.00	0
3	86.69	29.00	0	35	52.32	23.00	0
4	87.93	41.00	0	36	64.40	22.00	0
5	78.64	26.00	0	37	65.94	31.00	0
6	73.37	19.00	0	38	63.47	27.00	0
7	97.21	32.00	0	39	55.73	35.00	0
8	88.85	25.00	0	40	56.35	33.00	0
9	87.31	28.00	0	41	77.71	29.00	0
10	0.00	0.00	2	42	58.51	37.00	0
11	90.71	16.00	0	43	46.44	28.00	0
12	73.68	16.00	0	44	59.44	25.00	0
13	65.63	15.00	0	45	74.30	29.00	0
14	86.38	10.00	0	46	52.01	29.00	0
15	55.42	8.00	0	47	64.09	33.00	0
16	36.22	14.00	0	48	70.59	0.00	5
17	69.62	12.00	0	49	60.99	29.00	0
18	25.70	16.00	0	50	67.80	20.00	0
19	45.51	12.00	0	51	70.59	32.00	0
20	25.70	12.00	0	52	63.47	44.00	0
21	79.57	15.00	0	53	7.12	31.00	6
22	60.06	21.00	0	54	21.05	35.00	6
23	58.51	19.00	0	55	34.06	35.00	6
24	17.65	22.00	6	56	39.63	44.00	6
25	74.30	23.00	0	57	16.10	34.00	6
26	60.68	24.00	0	58	31.89	36.00	6
27	30.65	26.00	0	59	43.65	35.00	6
28	43.03	27.00	0	60	39.01	30.00	6
29	63.47	24.00	0	61	33.13	19.00	0
30	23.84	20.00	0	62	37.46	24.00	0
31	43.03	22.00	0	63	56.35	22.00	0
32	54.49	37.00	0	64	43.34	11.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.11 ILB50-4

ILB50-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	73.99	22.00	0	33	50.15	10.00	0
2	78.95	23.00	0	34	61.61	11.00	0
3	78.33	30.00	0	35	73.07	18.00	0
4	83.59	39.00	0	36	67.80	18.00	0
5	56.66	46.00	0	37	49.85	35.00	0
6	73.07	44.00	0	38	57.28	46.00	0
7	88.24	45.00	0	39	68.42	37.00	0
8	77.71	45.00	0	40	65.94	46.00	0
9	87.93	49.00	0	41	65.63	47.00	0
10	0.00	0.00	2	42	65.94	46.00	0
11	87.93	43.00	0	43	57.89	39.00	0
12	84.21	40.00	0	44	59.75	33.00	0
13	83.90	22.00	0	45	46.13	30.00	0
14	62.23	29.00	0	46	0.00	0.00	0
15	72.45	12.00	0	47	43.65	40.00	0
16	63.47	6.00	0	48	54.18	33.00	0
17	85.14	15.00	0	49	84.52	12.00	0
18	69.66	8.00	0	50	76.16	40.00	0
19	64.71	12.00	0	51	52.32	32.00	0
20	55.73	18.00	0	52	60.99	38.00	0
21	73.99	22.00	0	53	85.76	36.00	0
22	69.04	29.00	0	54	67.49	42.00	0
23	68.11	15.00	0	55	73.68	45.00	0
24	59.44	31.00	0	56	57.59	39.00	0
25	77.40	32.00	0	57	93.19	40.00	0
26	82.97	39.00	0	58	78.33	35.00	0
27	79.57	27.00	0	59	87.62	46.00	0
28	84.21	22.00	0	60	78.64	35.00	0
29	82.97	32.00	0	61	96.59	30.00	0
30	86.38	25.00	0	62	84.21	38.00	0
31	60.06	17.00	0	63	31.89	37.00	0
32	66.56	15.00	0	64	0.00	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.12 ILB50-5

ILB50-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high   Temperature: high   Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	90.40	7.00	1	33	81.73	35.00	0
2	70.90	30.00	0	34	94.12	35.00	0
3	79.88	35.00	0	35	58.20	35.00	0
4	44.89	36.00	0	36	62.85	35.00	0
5	77.09	0.00	3	37	78.64	35.00	0
6	80.50	37.00	0	38	84.52	38.00	0
7	51.39	37.00	0	39	77.09	40.00	0
8	68.42	39.00	0	40	69.04	39.00	0
9	30.03	38.00	0	41	84.52	39.00	0
10	0.00	0.00	2	42	89.16	32.00	0
11	56.97	40.00	0	43	58.82	30.00	0
12	32.51	36.00	0	44	64.71	32.00	0
13	86.69	22.00	0	45	74.30	8.00	1
14	79.26	27.00	0	46	68.73	16.00	0
15	66.25	18.00	0	47	80.80	29.00	0
16	65.63	14.00	0	48	87.93	20.00	0
17	0.00	0.00	0	49	64.09	17.00	0
18	65.02	10.00	0	50	90.40	12.00	0
19	52.01	19.00	0	51	88.85	24.00	0
20	34.67	18.00	0	52	64.09	36.00	0
21	64.40	27.00	0	53	72.14	36.00	0
22	74.92	31.00	0	54	57.28	37.00	0
23	68.42	32.00	0	55	51.08	38.00	0
24	56.97	35.00	0	56	61.30	37.00	0
25	40.56	33.00	0	57	64.71	38.00	0
26	43.34	37.00	0	58	71.21	31.00	0
27	75.54	24.00	0	59	77.71	30.00	0
28	64.09	35.00	0	60	91.33	23.00	0
29	0.00	0.00	0	61	0.00	0.00	0
30	97.21	30.00	0	62	78.95	25.00	0
31	90.71	19.00	0	63	72.76	26.00	0
32	33.44	21.00	0	64	79.57	28.00	0

Exclusion Code Legend:
- 0) accepted data point
- 1) arbitrarily suspicious point
- 2) not a real pin...vacant
- 3) pull tester didn't reset
- 4) known prior damage/handling
- 5) pull tester didn't record
- 6) unstored/unreadable SLAM
- 7) solder-bridged leads
- 8) pad lift (prior to pull?)
- 9) kapton-affected leads

Table A.1.13 ILB51-3

ILB51-3
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	45.20	30.00	0	33	19.81	17.00	0
2	64.40	37.00	0	34	64.09	32.00	0
3	49.54	37.00	0	35	51.70	22.00	0
4	73.99	32.00	0	36	50.15	24.00	0
5	45.82	26.00	0	37	39.63	27.00	0
6	66.87	26.00	0	38	54.49	25.00	0
7	24.46	0.00	5	39	53.25	24.00	0
8	24.46	38.00	0	40	43.03	29.00	0
9	48.92	33.00	0	41	30.65	25.00	0
10	0.00	0.00	2	42	46.13	25.00	0
11	53.25	26.00	0	43	33.75	26.00	0
12	34.37	26.00	0	44	33.13	21.00	0
13	41.49	21.00	0	45	29.10	17.00	0
14	36.84	18.00	0	46	32.51	14.00	0
15	34.37	16.00	0	47	53.56	12.00	0
16	29.72	10.00	0	48	22.60	18.00	0
17	37.77	15.00	0	49	73.99	34.00	0
18	60.06	19.00	0	50	69.35	41.00	0
19	37.15	20.00	0	51	74.30	43.00	0
20	9.29	27.00	0	52	88.54	40.00	0
21	35.29	23.00	0	53	43.96	55.00	0
22	60.99	29.00	0	54	78.95	54.00	0
23	73.68	29.00	0	55	79.88	61.00	0
24	43.06	28.00	0	56	51.08	48.00	0
25	45.82	25.00	0	57	45.51	48.00	0
26	54.80	29.00	0	58	73.37	48.00	0
27	65.02	30.00	0	59	81.42	32.00	0
28	49.85	28.00	0	60	56.97	28.00	0
29	59.75	27.00	0	61	72.21	24.00	0
30	54.80	20.00	0	62	52.32	22.00	0
31	51.39	18.00	0	63	41.18	20.00	0
32	70.28	18.00	0	64	39.94	21.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB51-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	91.33	34.00	0	33	84.21	31.00	0
2	83.90	46.00	0	34	89.16	42.00	0
3	82.04	22.00	0	35	77.40	46.00	0
4	69.97	43.00	0	36	0.00	0.00	8
5	39.94	16.00	0	37	12.38	0.00	8
6	54.49	40.00	0	38	61.92	43.00	0
7	0.00	0.00	8	39	73.37	45.00	0
8	64.71	44.00	0	40	80.80	42.00	0
9	54.49	48.00	0	41	93.50	50.00	0
10	0.00	0.00	2	42	81.73	48.00	0
11	0.00	0.00	0	43	82.04	45.00	0
12	62.85	42.00	0	44	83.90	41.00	0
13	48.92	33.00	0	45	65.02	36.00	0
14	56.04	22.00	0	46	77.09	30.00	0
15	54.80	28.00	0	47	69.35	31.00	0
16	55.73	28.00	0	48	61.30	26.00	0
17	46.13	22.00	0	49	56.04	18.00	0
18	73.99	37.00	0	50	78.33	16.00	0
19	59.44	24.00	0	51	45.51	19.00	0
20	66.25	37.00	0	52	71.52	28.00	0
21	60.37	38.00	0	53	52.63	38.00	0
22	42.72	22.00	0	54	83.59	46.00	0
23	34.67	33.00	0	55	67.80	47.00	0
24	31.89	32.00	0	56	40.87	45.00	0
25	33.13	33.00	0	57	60.06	50.00	0
26	70.28	37.00	0	58	73.07	[illegible]3.00	0
27	41.49	25.00	0	59	65.63	48.00	0
28	43.34	22.00	0	60	48.30	49.00	0
29	0.00	0.00	8	61	63.78	49.00	0
30	39.63	26.00	0	62	85.14	50.00	0
31	23.22	15.00	0	63	65.33	50.00	0
32	0.00	0.00	0	64	84.52	50.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.15 ILB51-5

ILB51-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	43.65	31.00	0	33	36.53	48.00	0
2	38.39	45.00	0	34	65.02	41.00	0
3	20.74	40.00	0	35	47.06	46.00	0
4	16.72	35.00	0	36	35.91	44.00	0
5	24.15	25.00	0	37	54.49	44.00	0
6	46.13	42.00	0	38	65.02	46.00	0
7	42.41	33.00	0	39	83.28	45.00	0
8	47.37	38.00	0	40	62.85	49.00	0
9	78.33	41.00	0	41	62.54	49.00	0
10	0.00	0.00	2	42	65.94	46.00	0
11	61.92	43.00	0	43	59.75	47.00	0
12	65.33	37.00	0	44	53.87	45.00	0
13	63.47	31.00	0	45	77.09	40.00	0
14	41.18	30.00	0	46	81.73	29.00	0
15	43.03	40.00	0	47	71.21	26.00	0
16	31.89	27.00	0	48	58.20	13.00	0
17	80.19	35.00	0	49	0.00	0.00	0
18	68.73	35.00	0	50	22.60	12.00	0
19	64.40	41.00	0	51	46.44	27.00	0
20	54.80	40.00	0	52	41.80	40.00	0
21	51.08	44.00	0	53	47.99	48.00	0
22	53.87	37.00	0	54	46.75	40.00	0
23	47.37	47.00	0	55	57.59	45.00	0
24	31.89	45.00	0	56	60.37	49.00	0
25	0.93	0.00	8	57	74.92	44.00	0
26	54.18	49.00	0	58	68.42	49.00	0
27	18.58	13.00	8	59	39.63	50.00	0
28	25.70	45.00	0	60	69.04	48.00	0
29	52.32	36.00	0	61	63.78	49.00	0
30	31.89	40.00	0	62	62.54	48.00	0
31	46.44	32.00	0	63	71.54	50.00	0
32	26.32	21.00	0	64	63.16	49.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.16 ILB52-3

ILB52-3
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	67.49	30.00	0	33	85.76	23.00	0
2	77.09	46.00	0	34	76.16	25.00	0
3	55.42	45.00	0	35	83.59	28.00	0
4	67.18	53.00	0	36	56.66	31.00	0
5	77.40	28.00	0	37	68.11	32.00	0
6	74.61	29.00	0	38	73.68	31.00	0
7	62.54	35.00	0	39	92.57	32.00	0
8	42.11	54.00	0	40	56.04	52.00	0
9	58.51	50.00	0	41	75.23	38.00	0
10	0.00	0.00	2	42	53.25	34.00	0
11	58.20	32.00	0	43	37.77	22.00	0
12	34.37	23.00	0	44	44.27	27.00	0
13	64.71	19.00	0	45	80.19	22.00	0
14	44.58	17.00	0	46	70.59	17.00	0
15	44.58	14.00	0	47	66.56	19.00	0
16	37.46	10.00	0	48	54.18	11.00	0
17	58.82	16.00	0	49	87.93	11.00	0
18	35.60	16.00	0	50	85.76	24.00	0
19	21.05	20.00	0	51	61.30	21.00	0
20	5.88	25.00	6	52	54.80	28.00	0
21	47.68	22.00	0	53	41.18	32.00	0
22	47.37	23.00	0	54	49.54	27.00	0
23	27.86	34.00	0	55	14.86	30.00	0
24	14.24	26.00	6	56	9.29	29.00	6
25	60.99	21.00	0	57	20.43	29.00	0
26	39.01	25.00	0	58	51.70	28.00	0
27	17.65	19.00	0	59	45.82	23.00	0
28	8.05	15.00	6	60	38.08	21.00	0
29	64.09	14.00	0	61	36.84	15.00	0
30	54.80	14.00	0	62	68.73	14.00	0
31	52.63	12.00	0	63	74.00	16.00	0
32	21.67	11.00	0	64	33.44	16.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.17 ILB52-4

ILB52-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	69.04	43.00	0	33	69.97	37.00	0
2	80.50	45.00	0	34	71.03	40.00	0
3	67.80	47.00	0	35	65.33	44.00	0
4	74.30	47.00	0	36	61.30	45.00	0
5	69.04	44.00	0	37	66.25	48.00	0
6	53.56	43.00	0	38	81.42	49.00	0
7	56.66	45.00	0	39	63.78	49.00	0
8	52.94	48.00	0	40	68.42	47.00	0
9	41.18	50.00	0	41	69.35	50.00	0
10	0.00	0.00	2	42	75.54	50.00	0
11	65.02	50.00	0	43	68.73	50.00	0
12	44.58	49.00	0	44	63.16	50.00	0
13	49.23	40.00	0	45	64.71	50.00	0
14	33.44	50.00	0	46	75.85	37.00	0
15	48.61	48.00	0	47	63.47	37.00	0
16	35.60	50.00	0	48	68.73	27.00	0
17	53.25	38.00	0	49	67.80	18.00	0
18	63.16	36.00	0	50	58.20	18.00	0
19	50.51	41.00	0	51	65.94	20.00	0
20	35.91	44.00	0	52	68.42	37.00	0
21	36.53	41.00	0	53	65.63	45.00	0
22	52.01	43.00	0	54	48.30	50.00	0
23	40.56	40.00	0	55	63.16	45.00	0
24	65.47	39.00	0	56	49.23	50.00	0
25	53.87	47.00	0	57	76.47	48.00	0
26	58.82	45.00	0	58	38.08	50.00	0
27	37.15	46.00	0	59	73.37	49.00	0
28	38.39	42.00	0	60	54.80	49.00	0
29	49.85	41.00	0	61	78.02	48.00	0
30	38.39	50.00	0	62	82.66	49.00	0
31	39.32	37.00	0	63	73.99	49.00	0
32	38.70	40.00	0	64	72.96	50.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.18 ILB52-5

ILB52-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	65.94	37.00	0	33	36.53	40.00	0
2	68.11	42.00	0	34	46.44	40.00	0
3	67.80	42.00	0	35	30.96	42.00	0
4	78.33	45.00	0	36	35.60	43.00	0
5	96.90	45.00	0	37	50.46	41.00	0
6	45.51	55.00	0	38	53.56	43.00	0
7	78.02	38.00	0	39	51.39	48.00	0
8	61.92	40.00	0	40	50.15	48.00	0
9	74.92	46.00	0	41	33.44	44.00	0
10	0.00	0.00	2	42	39.04	40.00	0
11	78.02	45.00	0	43	51.70	39.00	0
12	77.40	41.00	0	44	65.94	41.00	0
13	89.47	44.00	0	45	70.59	43.00	0
14	72.14	44.00	0	46	75.54	42.00	0
15	35.91	43.00	0	47	58.51	42.00	0
16	47.68	43.00	0	48	64.09	43.00	0
17	37.46	23.00	0	49	53.56	23.00	0
18	25.39	26.00	0	50	62.23	42.00	0
19	32.51	32.00	0	51	44.27	42.00	0
20	33.44	29.00	0	52	73.99	42.00	0
21	22.00	38.00	0	53	73.07	43.00	0
22	28.79	42.00	0	54	34.37	44.00	0
23	22.60	40.00	0	55	33.44	45.00	0
24	34.37	40.00	0	56	38.70	38.00	0
25	47.06	40.00	0	57	0.00	0.00	8
26	39.63	37.00	0	58	24.46	45.00	0
27	36.84	42.00	0	59	25.39	43.00	0
28	33.44	42.00	0	60	28.79	43.00	0
29	37.77	39.00	0	61	16.41	40.00	0
30	31.27	37.00	0	62	32.82	42.00	0
31	43.65	39.00	0	63	42.41	40.00	0
32	51.08	0.00	1	64	58.82	33.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.19 ILB53-2

ILB53-2
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	33.13	14.00	0	33	88.24	12.00	0
2	58.20	21.00	0	34	30.03	16.00	0
3	23.84	12.00	0	35	75.54	12.00	0
4	40.25	11.00	0	36	64.09	10.00	0
5	15.79	10.00	0	37	21.05	21.00	6
6	18.89	16.00	0	38	9.91	17.00	6
7	36.22	15.00	0	39	52.01	18.00	0
8	44.89	18.00	0	40	23.22	19.00	0
9	42.11	14.00	0	41	100.00	18.00	0
10	0.00	0.00	2	42	98.45	17.00	0
11	52.32	15.00	0	43	97.21	13.00	0
12	34.67	11.00	0	44	75.85	16.00	0
13	32.20	7.00	0	45	88.00	10.00	0
14	13.31	0.00	5	46	88.85	7.00	0
15	49.85	0.00	5	47	26.63	0.00	5
16	23.53	0.00	5	48	75.23	0.00	5
17	0.00	0.00	5	49	18.27	11.00	0
18	44.58	13.00	0	50	58.51	18.00	0
19	0.00	10.00	0	51	25.70	11.00	0
20	1.24	10.00	0	52	48.92	12.00	0
21	0.00	7.00	6	53	22.60	14.00	6
22	28.48	14.00	0	54	73.07	11.00	0
23	41.80	11.00	0	55	62.51	10.00	0
24	13.31	17.00	0	56	55.11	13.00	0
25	45.20	13.00	0	57	11.76	11.00	0
26	40.87	23.00	0	58	23.84	12.00	0
27	25.70	11.00	0	59	46.13	9.00	0
28	8.68	6.00	0	60	24.46	10.00	0
29	47.68	9.00	0	61	54.18	19.00	0
30	49.23	11.00	0	62	87.62	27.00	0
31	44.27	13.00	0	63	37.77	13.00	0
32	46.44	8.00	0	64	28.48	16.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.23 ILB53-5

ILB53-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	53.87	13.00	0	33	83.51	9.00	0
2	70.28	15.00	0	34	86.38	18.00	0
3	96.28	18.00	0	35	80.80	23.00	0
4	55.11	27.00	0	36	42.11	21.00	0
5	66.25	19.00	0	37	75.23	30.00	0
6	81.11	21.00	0	38	55.42	35.00	0
7	75.54	26.00	0	39	80.80	43.00	0
8	44.27	25.00	0	40	49.54	46.00	0
9	57.28	28.00	0	41	57.89	43.00	0
10	0.00	0.00	2	42	59.75	33.00	0
11	73.37	21.00	0	43	64.09	25.00	0
12	61.92	28.00	0	44	57.59	22.00	0
13	86.38	15.00	0	45	70.28	30.00	0
14	65.33	14.00	0	46	79.88	22.00	0
15	69.66	13.00	0	47	60.37	25.00	0
16	88.85	8.00	0	48	64.71	17.00	0
17	85.45	17.00	0	49	41.80	15.00	0
18	55.73	12.00	0	50	33.76	15.00	0
19	60.37	15.00	0	51	59.44	26.00	0
20	80.19	20.00	0	52	82.66	20.00	0
21	68.42	24.00	0	53	45.51	23.00	0
22	53.25	34.00	0	54	40.87	33.00	0
23	58.82	37.00	0	55	47.99	35.00	0
24	31.27	35.00	0	56	56.04	34.00	0
25	67.49	34.00	0	57	52.32	30.00	0
26	44.27	26.00	0	58	59.13	38.00	0
27	52.32	21.00	0	59	46.44	28.00	0
28	39.63	20.00	0	60	72.14	25.00	0
29	96.28	12.00	0	61	44.27	31.00	0
30	56.66	15.00	0	62	45.51	30.00	0
31	82.04	10.00	0	63	38.39	28.00	0
32	52.01	8.00	0	64	46.44	18.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.21 ILB54-4

ILB54-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	42.41	22.00	0	33	0.00	0.00	0
2	72.21	16.00	0	34	59.44	27.00	0
3	56.35	25.38	0	35	62.85	26.00	0
4	76.78	38.00	0	36	58.82	27.00	0
5	69.35	18.00	0	37	63.47	33.00	0
6	90.09	23.00	0	38	52.01	41.00	0
7	74.92	37.00	0	39	57.28	44.00	0
8	83.90	35.00	0	40	46.44	44.00	0
9	62.23	37.00	0	41	62.54	43.00	0
10	0.00	0.00	2	42	65.33	42.00	0
11	47.99	29.00	0	43	45.20	32.00	0
12	28.48	29.00	0	44	57.89	29.00	0
13	61.61	15.00	0	45	68.73	21.00	0
14	78.95	9.00	0	46	56.66	30.00	0
15	78.64	14.00	0	47	38.70	20.00	0
16	66.87	8.00	0	48	66.56	22.00	0
17	45.20	10.00	0	49	55.42	15.00	0
18	84.21	8.00	0	50	30.65	13.00	0
19	47.68	13.00	0	51	35.91	16.00	0
20	37.15	12.00	0	52	31.58	17.00	0
21	46.13	20.00	0	53	65.94	27.00	0
22	64.40	25.00	0	54	65.33	31.00	0
23	55.11	33.00	0	55	43.65	31.00	0
24	48.92	30.00	0	56	24.15	35.00	0
25	66.56	35.00	0	57	46.44	32.00	0
26	56.04	34.00	0	58	59.13	33.00	0
27	41.18	21.00	0	59	36.22	30.00	0
28	40.87	19.00	0	60	30.96	21.00	0
29	70.90	15.00	0	61	54.49	27.00	0
30	40.25	17.00	0	62	46.75	25.00	0
31	52.94	12.00	0	63	49.23	23.00	0
32	33.75	10.00	0	64	29.10	18.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.22 ILB55-5

ILB55-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	72.14	33.00	0
2	67.80	30.00	0
3	74.92	41.00	0
4	88.85	36.00	0
5	57.59	31.00	0
6	65.63	34.00	0
7	64.40	42.00	0
8	57.89	42.00	0
9	44.27	46.00	0
10	0.00	0.00	2
11	50.15	40.00	0
12	56.66	33.00	0
13	30.96	35.00	0
14	39.32	25.00	0
15	30.65	20.00	0
16	52.94	13.00	0
17	31.89	20.00	0
18	32.82	17.00	0
19	52.32	24.00	0
20	43.65	24.00	0
21	53.56	27.00	0
22	50.77	31.00	0
23	63.16	32.00	0
24	47.37	40.00	0
25	50.46	34.00	0
26	63.16	42.00	0
27	53.87	28.00	0
28	59.13	23.00	0
29	70.59	25.00	0
30	37.77	19.00	0
31	73.07	21.00	0
32	26.32	15.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	35.91	18.00	0
34	41.18	29.00	0
35	58.51	27.00	0
36	55.73	28.00	7
37	34.67	37.00	7
38	48.92	43.00	0
39	67.80	41.00	0
40	40.87	42.00	0
41	59.75	46.00	0
42	62.23	39.00	0
43	68.42	36.00	0
44	44.58	33.00	0
45	79.57	14.00	0
46	64.71	22.00	0
47	49.85	21.00	0
48	64.09	20.00	0
49	35.29	12.00	0
50	19.20	15.00	0
51	23.53	15.00	0
52	39.32	30.00	0
53	27.86	35.00	0
54	34.67	37.00	0
55	73.68	39.00	0
56	35.91	38.00	0
57	34.98	39.00	0
58	25.70	38.00	0
59	34.67	43.00	0
60	30.96	37.00	0
61	31.58	26.00	0
62	39.01	30.00	0
63	36.22	26.00	0
64	34.67	28.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.23 ILB57-4

ILB57-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: low   Temperature: high   Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	47.99	21.00	0	33	67.18	16.00	0
2	63.78	19.00	0	34	48.61	19.00	0
3	73.99	22.00	0	35	59.44	20.00	0
4	39.63	28.00	0	36	33.13	26.00	0
5	30.34	22.00	0	37	26.32	27.00	0
6	60.68	25.00	0	38	39.32	35.00	0
7	39.94	22.00	0	39	66.25	38.00	0
8	57.28	27.00	0	40	45.82	37.00	0
9	35.60	27.00	0	41	58.20	37.00	0
10	0.00	0.00	2	42	49.85	25.00	0
11	57.89	22.00	0	43	33.13	25.00	0
12	69.97	18.00	0	44	20.74	15.00	0
13	33.75	20.00	0	45	58.51	16.00	0
14	69.97	18.00	0	46	62.23	19.00	0
15	50.15	18.00	0	47	26.32	15.00	0
16	49.85	17.00	0	48	58.82	9.00	0
17	24.46	11.00	0	49	26.63	16.00	0
18	30.53	15.00	0	50	36.22	16.00	0
19	24.77	10.00	0	51	31.27	17.00	0
20	51.39	15.00	0	52	24.15	22.00	0
21	40.56	16.00	0	53	7.12	16.00	0
22	28.44	18.00	0	54	31.27	19.00	0
23	9.29	18.00	0	55	25.39	27.00	0
24	31.58	19.00	0	56	28.79	23.00	0
25	19.50	20.00	0	57	62.85	22.00	0
26	25.39	22.00	0	58	63.47	31.00	0
27	21.67	16.00	0	59	67.18	33.00	0
28	36.22	18.00	0	60	58.51	24.00	0
29	29.41	18.00	0	61	16.72	21.00	0
30	47.68	13.00	0	62	39.01	23.00	0
31	45.20	14.00	0	63	39.63	18.00	0
32	64.71	9.00	0	64	35.29	15.00	0

Exclusion Code Legend:
- 0) accepted data point
- 1) arbitrarily suspicious point
- 2) not a real pin...vacant
- 3) pull tester didn't reset
- 4) known prior damage/handling
- 5) pull tester didn't record
- 6) unstored/unreadable SLAM
- 7) solder-bridged leads
- 8) pad lift (prior to pull?)
- 9) kapton-affected leads

Table A.1.24 ILB59-2

ILB59-2

64 position solder TAB (position 10 vacant)

Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:

Pressure: low Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	39.94	0.00	5	33	17.03	0.00	5
2	61.30	7.00	0	34	46.44	0.00	5
3	67.80	0.00	5	35	53.25	8.00	0
4	60.06	0.00	5	36	58.51	0.00	5
5	13.00	6.00	0	37	30.65	0.00	5
6	59.75	12.00	0	38	49.23	8.00	0
7	57.28	0.00	5	39	18.58	7.00	0
8	47.99	8.00	0	40	41.49	0.00	5
9	43.96	0.00	5	41	75.54	0.00	5
10	0.00	0.00	2	42	84.83	8.00	0
11	38.08	0.00	5	43	90.40	0.00	5
12	31.89	0.00	5	44	29.72	7.00	0
13	58.51	0.00	5	45	76.47	0.00	5
14	46.75	0.00	5	46	75.54	8.00	0
15	92.57	0.00	5	47	77.71	0.00	5
16	47.68	0.00	5	48	70.28	0.00	5
17	62.85	0.00	5	49	77.71	10.00	0
18	65.94	0.00	5	50	91.02	0.00	5
19	64.71	6.00	0	51	79.26	7.00	0
20	7.74	0.00	5	52	53.25	0.00	5
21	56.97	0.00	5	53	79.57	8.00	0
22	15.75	6.00	0	54	69.35	0.00	5
23	39.32	0.00	5	55	57.89	0.00	5
24	0.93	0.00	5	56	32.20	6.00	0
25	8.67	0.00	5	57	42.41	0.00	5
26	15.48	6.00	0	58	51.70	0.00	5
27	4.02	0.00	5	59	39.94	8.00	0
28	0.00	0.00	5	60	16.72	8.00	0
29	0.00	0.00	5	61	41.80	0.00	5
30	0.00	0.00	5	62	43.34	0.00	5
31	14.24	0.00	5	63	39.63	0.00	5
32	28.48	0.00	5	64	20.12	0.00	5

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.25 ILB59-3

ILB59-3
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	77.71	0.00	4	33	78.02	0.00	5
2	22.29	0.00	4	34	68.11	10.00	0
3	1.86	0.00	5	35	0.93	11.00	0
4	12.07	8.00	0	36	12.38	6.00	0
5	18.58	8.00	0	37	79.57	10.00	0
6	20.12	7.00	0	38	51.39	9.00	0
7	1.24	7.00	0	39	57.59	10.00	0
8	2.79	7.00	0	40	29.72	8.00	0
9	17.65	9.00	0	41	74.61	9.00	0
10	0.00	0.00	2	42	90.40	12.00	0
11	3.72	9.00	0	43	64.71	8.00	0
12	0.00	7.00	0	44	47.68	8.00	0
13	66.87	0.00	5	45	66.26	7.00	0
14	13.62	0.00	5	46	37.77	0.00	5
15	17.03	0.00	5	47	48.61	0.00	5
16	11.76	0.00	5	48	56.66	0.00	5
17	26.93	7.00	0	49	73.68	14.00	0
18	37.77	10.00	0	50	61.61	13.00	0
19	1.24	7.00	0	51	66.25	13.00	0
20	0.93	8.00	0	52	13.31	18.00	0
21	6.19	8.00	0	53	76.16	14.00	0
22	4.64	7.00	0	54	53.87	10.00	0
23	21.98	7.00	0	55	11.76	7.00	0
24	0.00	6.00	0	56	0.00	13.00	6
25	29.41	6.00	0	57	77.09	16.00	0
26	24.77	7.00	0	58	73.37	13.00	0
27	14.86	0.00	5	59	59.75	13.00	0
28	17.65	0.00	5	60	6.81	11.00	0
29	54.80	0.00	5	61	79.88	6.00	0
30	56.35	0.00	5	62	51.08	8.00	0
31	4.02	0.00	5	63	66.56	0.00	5
32	15.17	0.00	5	64	33.75	0.00	5

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.26 ILB59-4

ILB59-4
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	1.86	0.00	0	33	28.79	4.00	0
2	20.74	5.00	0	34	64.09	8.00	0
3	0.00	0.00	0	35	40.56	4.00	0
4	1.55	0.00	0	36	30.65	4.00	0
5	78.33	6.00	0	37	80.19	8.00	0
6	6.81	0.00	0	38	77.40	7.00	0
7	87.00	6.00	0	39	59.13	7.00	0
8	13.93	0.00	0	40	52.94	5.00	0
9	86.33	12.00	0	41	89.47	9.00	0
10	0.00	0.00	2	42	69.66	9.00	0
11	82.66	7.00	0	43	59.44	0.00	0
12	2.17	0.00	0	44	63.47	5.00	0
13	69.66	5.00	0	45	43.65	7.00	0
14	84.52	8.00	0	46	8.05	0.00	0
15	0.00	0.00	0	47	2.79	0.00	0
16	15.48	0.00	0	48	4.95	0.00	0
17	59.44	0.00	0	49	13.93	0.00	0
18	9.91	5.00	0	50	64.09	8.00	0
19	65.02	0.00	0	51	22.91	0.00	0
20	65.02	6.00	0	52	75.23	4.00	0
21	2.48	0.00	0	53	0.00	0.00	0
22	77.71	10.00	0	54	66.56	9.00	0
23	7.12	0.00	0	55	67.80	14.00	0
24	5.26	0.00	0	56	23.84	3.00	0
25	2.48	0.00	0	57	52.94	12.00	0
26	30.34	0.00	0	58	74.30	11.00	0
27	2.79	0.00	0	59	78.64	11.00	0
28	73.99	5.00	0	60	59.13	3.00	0
29	40.87	5.00	0	61	31.27	4.00	0
30	53.25	7.00	0	62	44.89	0.00	0
31	40.56	3.00	0	63	0.00	0.00	0
32	27.55	0.00	0	64	50.46	3.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.27 ILB60-2

ILB60-2
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	64.71	11.00	0	33	71.52	11.00	0
2	79.88	10.00	0	34	63.78	8.00	0
3	66.56	6.00	0	35	50.15	10.00	0
4	95.36	0.00	5	36	42.41	9.00	0
5	39.32	8.00	0	37	52.01	0.00	5
6	56.65	13.00	0	38	69.04	8.00	0
7	55.73	10.00	0	39	56.66	8.00	0
8	45.51	8.00	0	40	88.85	6.00	0
9	61.61	0.00	5	41	66.87	0.00	5
10	0.00	0.00	2	42	83.30	6.00	0
11	44.58	6.00	0	43	67.18	0.00	5
12	2.48	8.00	0	44	87.31	0.00	5
13	17.34	9.00	0	45	70.59	0.00	5
14	0.00	6.00	0	46	75.85	0.00	5
15	22.29	0.00	5	47	68.11	0.00	5
16	4.95	0.00	5	48	86.07	0.00	5
17	0.00	0.00	5	49	57.28	0.00	5
18	33.75	0.00	5	50	74.30	8.00	0
19	1.86	11.00	0	51	74.92	0.00	5
20	34.98	10.00	0	52	62.23	10.00	0
21	29.41	0.00	5	53	92.88	0.00	5
22	57.89	0.00	5	54	64.71	0.00	5
23	21.98	13.00	0	55	78.95	0.00	5
24	16.10	0.00	5	56	66.56	0.00	5
25	18.58	8.00	0	57	33.75	0.00	5
26	56.04	0.00	5	58	92.57	0.00	5
27	33.75	10.00	0	59	53.25	0.00	5
28	60.37	12.00	0	60	50.77	0.00	5
29	51.39	7.00	0	61	27.55	0.00	5
30	75.84	8.00	0	62	64.40	0.00	5
31	53.25	9.00	0	63	48.61	0.00	5
32	15.48	0.00	5	64	21.67	0.00	5

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.28 ILB61-5

ILB61-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	54.18	15.00	0	33	77.09	10.00	0
2	41.80	13.00	0	34	47.99	13.00	0
3	33.44	12.00	0	35	63.16	14.00	0
4	35.91	15.00	0	36	79.57	14.00	0
5	59.75	12.00	0	37	48.61	19.00	0
6	46.44	20.00	0	38	41.49	25.00	0
7	82.35	33.00	0	39	50.46	28.00	0
8	50.46	31.00	0	40	68.42	31.00	0
9	34.37	41.00	0	41	61.92	33.00	0
10	0.00	0.00	2	42	60.86	27.00	0
11	51.08	14.00	0	43	71.83	24.00	0
12	36.22	35.00	0	44	60.68	15.00	0
13	80.50	15.00	0	45	56.66	16.00	0
14	85.45	19.00	0	46	34.37	12.00	0
15	69.97	10.00	0	47	53.25	20.00	0
16	69.04	12.00	0	48	54.80	13.00	0
17	50.77	13.00	0	49	41.49	11.00	0
18	47.99	10.00	0	50	72.76	10.00	0
19	31.58	15.00	0	51	47.06	15.00	0
20	17.03	17.00	0	52	55.11	17.00	0
21	20.43	16.00	0	53	59.44	10.00	0
22	25.08	15.00	0	54	71.83	17.00	0
23	29.72	18.00	0	55	64.71	15.00	0
24	11.15	13.00	0	56	77.09	23.00	0
25	45.51	17.00	0	57	46.13	22.00	0
26	27.86	15.00	0	58	54.49	20.00	0
27	51.39	26.00	0	59	42.72	25.00	0
28	61.61	26.00	0	60	66.87	21.00	0
29	48.30	16.00	0	61	61.92	12.00	0
30	33.44	15.00	0	62	34.67	16.00	0
31	49.85	17.00	0	63	67.18	12.00	0
32	82.66	14.00	0	64	57.28	15.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.1.29 ILB62-5

ILB62-5
64 position solder TAB (position 10 vacant)
Inner-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	75.23	12.00	0	33	65.02	8.00	0
2	28.79	12.00	0	34	54.18	10.00	0
3	41.18	13.00	0	35	27.24	15.00	0
4	43.34	20.00	0	36	44.58	13.00	0
5	45.20	18.00	0	37	52.63	17.00	0
6	41.80	14.00	0	38	69.97	27.00	0
7	28.17	15.00	0	39	49.23	33.00	0
8	17.65	8.00	0	40	53.25	41.00	0
9	20.43	30.00	0	41	80.19	35.00	0
10	0.00	0.00	2	42	78.02	30.00	0
11	33.13	20.00	0	43	39.32	20.00	0
12	49.23	17.00	0	44	59.44	12.00	0
13	38.08	15.00	0	45	62.85	17.00	0
14	28.48	12.00	0	46	79.57	15.00	0
15	15.48	15.00	0	47	44.58	17.00	0
16	0.00	0.00	8	48	45.82	10.00	0
17	20.74	16.00	0	49	0.00	11.00	6
18	30.34	13.00	0	50	0.00	13.00	6
19	11.76	11.00	0	51	0.00	12.00	6
20	23.84	14.00	0	52	0.00	12.00	6
21	18.89	16.00	0	53	58.82	16.00	0
22	18.58	17.00	0	54	47.37	18.00	0
23	8.36	22.00	0	55	24.77	22.00	0
24	38.08	18.00	0	56	28.17	23.00	0
25	6.50	20.00	0	57	46.44	23.00	0
26	15.17	19.00	0	58	53.56	25.00	0
27	18.89	15.00	0	59	33.13	22.00	0
28	35.29	15.00	0	60	34.06	21.00	0
29	30.03	15.00	0	61	67.49	18.00	0
30	24.77	18.00	0	62	49.23	17.00	0
31	21.05	17.00	0	63	69.66	14.00	0
32	10.53	7.00	0	64	75.85	10.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2 OLB Samples

OLB Samples (solder TAB)

BONDING CONDITIONS: dwell time, temperature, pressure

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	pressure / temperature / dwell time
OLB16-2	97.15	33.64	34.04	141.00	11.62	12.00	1	2	GTE	LMH
OLB17-3	53.60	9.00	8.97	77.00	4.12	4.26	1	2	SS	LMM
OLB21-2	89.79	28.64	29.10	59.00	5.91	6.00	1	2	GTE	LHH
OLB21-3	95.80	46.08	49.43	50.00	32.59	32.75	4	6	SS	LHH
OLB24-6	83.78	10.73	11.02	31.00	4.08	4.21	1	2	SS	MLH
OLB25-5	77.78	16.04	15.91	44.00	7.12	7.03	2	7	SS	HLH
OLB28-2	77.78	20.66	19.33	83.00	11.56	12.33	2	5	GTE	MMH
OLB28-4	88.74	31.49	32.00	49.00	24.69	24.49	2	7	SS	MMH
OLB29-2	87.84	28.22	29.13	93.00	17.81	17.58	1	2	GTE	HMH
OLB29-5	83.78	32.26	32.77	32.00	9.47	9.62	1	2	SS.	HMH
OLB31-2	93.69	32.49	36.49	103.00	17.80	28.48	23	4	GTE	HMM
OLB33-2	86.19	47.31	53.59	61.00	21.67	26.67	10	4	GTE	HHM
OLB33-6	50.45	19.90	20.21	37.00	7.47	7.59	1	2	SS	HHM
OLB34-2	92.94	58.31	61.25	67.00	29.52	34.35	5	5	GTE	HHL
OLB34-3	91.74	44.48	46.21	50.00	24.91	26.13	2	3	SS	HHL
OLB35-2	93.54	38.46	38.42	100.00	25.69	26.52	1	2	GTE	MHH
OLB35-4	93.54	60.92	61.88	120.00	75.31	76.51	1	2	SS	MHH
OLB35-6	95.50	66.09	66.89	125.00	65.97	70.37	3	5	SS	MHH
OLB36-2	70.27	27.04	23.89	44.00	3.64	5.68	22	4	GTE	MHM
OLB36-4	87.24	36.24	36.81	46.00	22.34	22.70	1	2	SS	MHM
OLB37-2	94.44	37.94	39.97	42.00	5.78	8.22	18	4	GTE	MHL
OLB37-4	57.96	18.33	19.86	40.00	4.86	5.58	13	9	SS	MHL
OLB38-2	93.24	33.79	31.40	30.00	3.97	5.18	13	4	GTE	MMM
OLB38-5	72.07	29.90	30.38	47.00	16.73	17.00	1	2	SS	MMM

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.1 OLB16-2

OLB16-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	64.41	83.00	0	33	3.90	0.00	0
2	70.57	57.00	0	34	3.60	0.00	0
3	69.67	19.00	0	35	7.51	0.00	0
4	88.74	39.00	0	36	7.81	0.00	0
5	42.64	0.00	5	37	7.51	0.00	0
6	72.37	0.00	1	38	23.57	0.00	1
7	94.29	71.00	0	39	3.45	0.00	0
8	90.24	26.00	0	40	6.01	0.00	0
9	95.65	16.00	0	41	37.84	0.00	1
10	0.00	0.00	2	42	50.60	0.00	1
11	93.99	0.00	1	43	18.92	0.00	1
12	97.15	141.00	0	44	30.03	0.00	1
13	88.59	0.00	1	45	13.06	0.00	1
14	95.20	24.00	0	46	9.61	0.00	0
15	91.59	16.00	0	47	9.01	0.00	0
16	75.68	8.00	1	48	4.35	0.00	0
17	21.62	0.00	1	49	27.48	0.00	1
18	28.23	0.00	1	50	8.41	12.00	0
19	54.95	0.00	1	51	24.47	26.00	0
20	1.05	0.00	0	52	27.03	13.00	0
21	0.30	0.00	0	53	28.83	11.00	0
22	0.30	0.00	0	54	51.35	95.00	0
23	3.30	0.00	0	55	58.11	37.00	0
24	61.26	8.00	0	56	8.26	0.00	0
25	1.20	24.00	0	57	16.22	0.00	1
26	1.65	0.00	0	58	60.81	0.00	1
27	9.16	0.00	0	59	36.04	0.00	1
28	5.71	0.00	0	60	72.67	18.00	0
29	0.30	0.00	0	61	16.82	0.00	1
30	2.40	0.00	0	62	0.30	0.00	0
31	1.80	0.00	0	63	0.15	0.00	0
32	54.95	0.00	1	64	0.19	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.2 OLB17-3

OLB17-3
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: low Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	2.10	0.00	0	33	0.00	0.00	0
2	0.60	0.00	0	34	16.22	0.00	0
3	43.39	11.00	0	35	24.00	77.00	0
4	4.50	0.00	0	36	12.31	0.00	0
5	3.30	0.00	0	37	6.01	5.00	0
6	4.95	0.00	0	38	5.11	0.00	0
7	13.36	0.00	0	39	7.96	0.00	0
8	5.71	0.00	0	40	12.16	0.00	0
9	9.16	8.00	0	41	6.91	0.00	0
10	0.00	0.00	2	42	15.92	6.00	0
11	1.65	0.00	0	43	31.53	7.00	0
12	3.30	0.00	0	44	10.06	4.00	0
13	0.00	0.00	0	45	15.92	3.00	0
14	0.45	0.00	0	46	10.66	0.00	0
15	39.19	7.00	0	47	17.27	0.00	0
16	3.90	0.00	0	48	19.22	0.00	0
17	0.15	0.00	0	49	3.45	0.00	0
18	0.00	0.00	0	50	1.20	0.00	0
19	1.95	0.00	0	51	1.35	0.00	0
20	7.36	0.00	0	52	0.75	0.00	0
21	0.00	0.00	0	53	1.35	0.00	0
22	0.90	0.00	0	54	1.20	0.00	0
23	5.41	0.00	0	55	0.00	0.00	0
24	16.07	40.00	0	56	0.60	0.00	0
25	13.21	15.00	0	57	0.15	0.00	0
26	7.66	9.00	0	58	3.30	0.00	0
27	2.70	0.00	0	59	3.30	0.00	0
28	20.12	0.00	5	60	4.05	0.00	0
29	33.48	36.00	0	61	0.00	0.00	0
30	34.98	22.00	0	62	1.05	0.00	0
31	0.90	0.00	0	63	0.30	0.00	0
32	53.60	14.00	0	64	8.71	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.3 OLB21-2

OLB21-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: low Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	16.22	0.00	0	33	0.15	0.00	0
2	51.35	25.00	0	34	0.30	0.00	0
3	30.33	58.00	0	35	2.55	0.00	0
4	53.30	59.00	0	36	5.41	0.00	0
5	46.55	0.00	1	37	2.85	0.00	0
6	56.76	40.00	0	38	40.24	0.00	1
7	72.97	42.00	0	39	14.56	0.00	0
8	80.78	29.00	0	40	59.91	0.00	1
9	75.08	24.00	0	41	63.81	0.00	1
10	0.00	0.00	2	42	53.90	0.00	1
11	73.72	27.00	0	43	87.24	31.00	0
12	66.52	9.00	0	44	89.79	15.00	0
13	28.83	0.00	0	45	62.31	0.00	1
14	55.71	12.00	0	46	0.15	0.00	0
15	42.79	0.00	1	47	24.62	0.00	0
16	0.30	0.00	0	48	23.87	0.00	0
17	26.73	0.00	0	49	30.33	0.00	1
18	9.46	0.00	0	50	2.55	0.00	0
19	0.15	0.00	0	51	0.45	0.00	0
20	3.75	0.00	0	52	49.25	0.00	1
21	0.15	0.00	0	53	9.16	7.00	0
22	22.82	0.00	0	54	11.11	0.00	0
23	12.31	0.00	0	55	17.27	0.00	0
24	31.23	0.00	1	56	40.84	0.00	1
25	26.73	0.00	0	57	21.92	0.00	0
26	4.95	0.00	0	58	10.36	0.00	0
27	42.94	0.00	0	59	0.00	0.00	0
28	71.47	0.00	1	60	0.45	0.00	0
29	20.87	0.00	0	61	0.30	0.00	0
30	1.35	0.00	0	62	0.00	0.00	0
31	2.85	0.00	0	63	0.15	0.00	0
32	78.23	0.00	1	64	0.15	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.4 OLB21-3

OLB21-3
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: low Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	0
2	47.15	24.00	0
3	79.88	40.00	0
4	85.29	43.00	0
5	83.33	35.00	0
6	53.75	47.00	0
7	89.49	42.00	0
8	89.64	45.00	0
9	65.62	43.00	0
10	0.00	0.00	2
11	87.69	50.00	0
12	95.80	48.00	0
13	68.02	42.00	0
14	92.19	46.00	0
15	76.73	45.00	0
16	76.43	42.00	0
17	28.23	46.00	6
18	0.05	24.00	6
19	60.81	45.00	0
20	62.61	41.00	0
21	0.15	42.00	6
22	4.50	42.00	6
23	21.77	41.00	0
24	52.70	41.00	0
25	22.67	48.00	0
26	57.36	43.00	0
27	45.20	44.00	0
28	68.32	46.00	0
29	33.33	45.00	0
30	59.16	42.00	0
31	68.77	33.00	0
32	78.38	21.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	50.60	20.00	0
34	67.12	38.00	0
35	77.63	31.00	0
36	79.43	40.00	0
37	36.94	43.00	0
38	43.84	18.00	0
39	39.79	18.00	0
40	70.27	48.00	0
41	50.60	41.00	0
42	61.26	33.00	0
43	48.80	24.00	0
44	59.01	25.00	0
45	32.28	10.00	0
46	18.77	0.00	1
47	44.74	27.00	0
48	60.51	39.00	0
49	24.32	41.00	0
50	55.11	45.00	0
51	34.83	12.00	0
52	47.45	24.00	0
53	3.90	25.00	0
54	14.26	7.00	0
55	16.52	15.00	0
56	4.80	0.00	0
57	9.31	41.00	0
58	19.52	37.00	0
59	0.75	16.00	0
60	49.55	36.00	0
61	6.76	41.00	0
62	7.06	0.00	0
63	54.05	42.00	0
64	4.50	13.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.5 OLB24-6

OLB24-6
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: low Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.45	0.00	0	33	2.40	0.00	0
2	3.75	0.00	4	34	0.75	0.00	0
3	33.48	7.00	0	35	0.30	0.00	0
4	51.65	15.00	0	36	14.56	0.00	0
5	34.23	11.00	0	37	1.50	0.00	0
6	54.65	17.00	0	38	9.91	0.00	0
7	38.89	22.00	0	39	1.05	0.00	0
8	71.62	23.00	0	40	0.15	0.00	0
9	20.57	10.00	0	41	0.30	0.00	0
10	0.00	0.00	2	42	0.45	0.00	0
11	67.57	31.00	0	43	0.15	0.00	0
12	83.78	27.00	0	44	1.20	0.00	0
13	53.30	25.00	0	45	0.00	0.00	0
14	11.86	5.00	0	46	0.30	0.00	0
15	4.20	7.00	0	47	0.15	0.00	0
16	8.41	0.00	0	48	2.25	0.00	0
17	0.00	0.00	0	49	1.05	5.00	0
18	0.00	0.00	0	50	0.00	0.00	0
19	0.00	0.00	0	51	0.15	0.00	0
20	1.05	0.00	0	52	23.72	10.00	0
21	1.80	0.00	0	53	12.61	13.00	0
22	7.96	0.00	0	54	4.65	0.00	0
23	19.67	20.00	0	55	0.60	0.00	0
24	6.46	0.00	0	56	4.05	0.00	0
25	0.00	0.00	0	57	0.00	0.00	0
26	0.90	0.00	0	58	3.00	0.00	0
27	2.85	0.00	0	59	1.65	0.00	0
28	1.50	10.00	0	60	2.40	0.00	0
29	1.50	0.00	0	61	1.20	0.00	0
30	0.30	0.00	0	62	0.15	0.00	0
31	2.40	0.00	0	63	0.75	0.00	0
32	2.85	8.00	0	64	7.81	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.6 OLB25-5

OLB25-5
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: low Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.15	0.00	0
2	16.37	14.00	0
3	62.76	25.00	0
4	77.78	33.00	0
5	44.29	28.00	0
6	20.72	41.00	0
7	62.61	44.00	0
8	55.86	27.00	0
9	1.95	0.00	0
10	0.00	0.00	2
11	1.95	0.00	0
12	49.40	20.00	0
13	1.05	0.00	0
14	27.33	12.00	0
15	0.15	0.00	0
16	0.75	0.00	0
17	21.77	27.00	0
18	35.59	25.00	0
19	8.41	0.00	0
20	12.16	0.00	0
21	3.90	0.00	0
22	9.76	0.00	0
23	11.41	0.00	0
24	4.35	0 00	0
25	6.46	0.00	0
26	7.96	0.00	0
27	6.46	0.00	0
28	8.58	0.00	0
29	4.95	0.00	0
30	0.75	0.00	0
31	7.66	0.00	0
32	3.60	0.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	1.20	0.00	0
34	0.15	0.00	0
35	0.60	0.00	0
36	3.45	0.00	0
37	40.69	21.00	0
38	28.38	19.00	0
39	65.17	20.00	0
40	50.90	18.00	0
41	24.32	21.00	0
42	22.97	17.00	0
43	19.82	15.00	0
44	34.98	14.00	7
45	21.02	13.00	7
46	16.97	0.00	0
47	18.47	0.00	0
48	0.50	0.00	0
49	0.00	0.00	0
50	0.00	0.00	0
51	22.07	6.00	0
52	27.93	15.00	0
53	0.15	0.00	0
54	10.51	7.00	0
55	12.61	0.00	0
56	3.75	0.00	0
57	0.15	0.00	0
58	4.95	0.00	0
59	4.50	0.00	0
60	3.30	0.00	0
61	0.00	0.00	0
62	1.95	0.00	0
63	5.41	0.00	0
64	2.70	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.7 OLB28-2

OLB28-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	0	33	61.41	21.00	0
2	0.00	0.00	0	34	61.71	34.00	0
3	0.45	0.00	0	35	71.92	42.00	0
4	0.15	0.00	0	36	70.72	35.00	0
5	0.00	0.00	0	37	50.90	35.00	0
6	0.00	0.00	0	38	52.40	53.00	0
7	0.00	0.00	0	39	57.21	40.00	0
8	5.56	0.00	0	40	67.57	45.00	0
9	0.00	0.00	0	41	68.82	40.00	0
10	0.00	0.00	2	42	76.73	61.00	0
11	0.00	0.00	0	43	67.87	0.00	4
12	0.45	0.00	0	44	77.78	58.00	0
13	0.00	0.00	0	45	53.30	0.00	5
14	0.15	0.00	0	46	49.55	23.00	0
15	0.00	0.00	0	47	52.40	28.00	0
16	0.75	0.00	0	48	77.63	33.00	0
17	1.95	0.00	0	49	0.45	0.00	0
18	0.00	0.00	0	50	18.47	0.00	0
19	0.60	0.00	0	51	19.07	34.00	0
20	3.90	0.00	0	52	8.56	15.00	0
21	0.15	0.00	0	53	1.35	0.00	0
22	2.10	0.00	0	54	0.60	0.00	0
23	0.15	0.00	0	55	31.68	0.00	1
24	3.30	0.00	0	56	15.32	0.00	0
25	0.15	0.00	0	57	2.85	0.00	0
26	8.26	0.00	0	58	23.57	20.00	0
27	0.00	0.00	0	59	1.80	0.00	0
28	46.55	83.00	0	60	2.25	0.00	0
29	0.00	0.00	0	61	0.00	0.00	0
30	0.00	0.00	0	62	0.30	0.00	0
31	57.06	40.00	0	63	2.10	0.00	0
32	41.44	0.00	5	64	2.85	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.8 OLB28-4

OLB28-4
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	0
2	12.31	28.00	0
3	1.80	0.00	0
4	52.85	47.00	0
5	0.15	0.00	0
6	2.70	0.00	0
7	3.00	0.00	0
8	0.75	0.00	0
9	0.00	0.00	0
10	0.00	0.00	2
11	1.05	0.00	0
12	9.61	0.00	0
13	0.00	0.00	0
14	63.21	33.00	0
15	66.52	35.00	0
16	88.74	31.00	0
17	18.77	14.00	0
18	43.54	13.00	0
19	49.25	34.00	0
20	43.84	31.00	0
21	32.13	40.00	0
22	32.28	43.00	0
23	39.19	42.00	0
24	54.80	38.00	0
25	11.86	30.00	0
26	44.29	45.00	0
27	43.54	44.00	0
28	60.06	45.00	0
29	27.18	38.00	0
30	49.55	37.00	0
31	21.32	45.00	7
32	42.04	41.00	7

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	60.66	23.00	0
34	65.77	33.00	0
35	67.12	29.00	0
36	69.82	44.00	0
37	46.70	44.00	0
38	60.51	49.00	0
39	59.31	45.00	0
40	11.26	0.00	0
41	0.15	0.00	0
42	16.67	46.00	0
43	3.60	0.00	0
44	54.80	44.00	0
45	35.44	45.00	0
46	26.43	37.00	0
47	39.79	19.00	0
48	0.00	0.00	0
49	22.52	44.00	0
50	51.95	43.00	0
51	59.91	41.00	0
52	71.77	45.00	0
53	0.00	0.00	0
54	0.15	0.00	0
55	0.00	0.00	0
56	3.75	0.00	0
57	0.00	0.00	0
58	0.00	0.00	0
59	55.41	34.00	0
60	63.51	44.00	0
61	45.80	35.00	0
62	53.00	43.00	0
63	24.02	25.00	0
64	28.98	14.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.9 OLB29-2

OLB29-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	58.26	23.00	0	33	36.06	11.00	0
2	51.95	32.00	0	34	42.79	27.00	0
3	1.35	0.00	0	35	17.27	32.00	0
4	6.31	0.00	0	36	45.35	32.00	0
5	4.50	0.00	0	37	0.30	0.00	0
6	13.21	0.00	0	38	2.10	0.00	0
7	1.35	0.00	0	39	0.60	0.00	0
8	3.00	0.00	0	40	14.26	0.00	0
9	74.47	12.00	0	41	1.35	0.00	0
10	0.00	0.00	2	42	0.00	0.00	0
11	2.10	0.00	0	43	6.91	0.00	0
12	5.41	0.00	0	44	31.83	0.00	1
13	0.00	0.00	0	45	28.38	6.00	0
14	0.60	0.00	0	46	29.88	0.00	0
15	87.84	0.00	1	47	31.53	13.00	0
16	81.38	0.00	1	48	39.49	0.00	1
17	27.33	27.00	0	49	25.83	23.00	0
18	31.23	17.00	0	50	35.89	20.00	0
19	39.19	15.00	0	51	31.83	19.00	0
20	40.09	10.00	0	52	50.30	67.00	0
21	38.29	34.00	0	53	52.25	93.00	0
22	33.18	19.00	0	54	50.30	93.00	0
23	61.26	49.00	0	55	38.14	30.00	0
24	69.22	38.00	0	56	16.67	0.00	0
25	0.00	50.00	6	57	47.90	69.00	0
26	23.57	54.00	0	58	49.70	80.00	0
27	32.58	42.00	0	59	41.44	23.00	0
28	41.74	36.00	0	60	34.83	18.00	0
29	34.83	27.00	0	61	7.66	0.00	0
30	24.92	7.00	0	62	0.00	0.00	0
31	38.59	32.00	0	63	0.60	0.00	0
32	31.98	41.00	0	64	35.14	12.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

OLB29-5
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.30	0.00	0	33	15.32	0.00	0
2	39.34	17.00	0	34	48.05	11.00	0
3	47.00	19.00	0	35	58.11	19.00	0
4	68.17	12.00	0	36	80.93	18.00	0
5	9.31	0.00	0	37	46.85	13.00	0
6	17.72	0.00	0	38	38.74	15.00	0
7	41.44	8.00	0	39	50.00	15.00	0
8	60.36	25.00	0	40	57.21	22.00	0
9	56.46	9.00	0	41	37.69	13.00	0
10	0.00	0.00	2	42	50.15	15.00	0
11	69.97	30.00	0	43	77.33	27.00	0
12	69.82	21.00	0	44	80.48	19.00	0
13	50.15	16.00	0	45	38.29	12.00	0
14	55.26	17.00	0	46	48.20	7.00	0
15	38.59	15.00	0	47	83.78	8.00	0
16	41.44	32.00	0	48	68.47	8.00	0
17	32.58	15.00	0	49	18.77	0.00	0
18	17.27	15.00	0	50	53.15	9.00	0
19	2.10	0.00	0	51	19.05	0.00	0
20	3.45	7.00	0	52	23.57	0.00	0
21	14.41	0.00	0	53	0.00	0.00	0
22	13.51	0.00	0	54	11.11	0.00	0
23	14.41	0.00	0	55	18.62	0.00	0
24	12.16	0.00	0	56	28.53	0.00	0
25	0.15	0.00	0	57	4.95	0.00	0
26	0.90	0.00	0	58	5.86	0.00	0
27	1.65	0.00	0	59	29.28	24.00	0
28	29.88	27.00	0	60	13.66	0.00	0
29	23.12	13.00	0	61	0.60	0.00	0
30	47.15	22.00	0	62	0.60	0.00	0
31	51.65	17.00	0	63	13.36	0.00	0
32	46.10	11.00	0	64	15.02	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.11 OLB31-2

OLB31-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	50.30	15.00	0	33	27.33	9.00	0
2	73.12	24.00	0	34	36.64	13.00	0
3	65.77	77.00	0	35	46.70	16.00	0
4	93.69	75.00	0	36	0.75	0.00	4
5	46.55	62.00	0	37	46.55	37.00	0
6	69.37	100.00	0	38	29.73	23.00	0
7	58.71	103.00	0	39	51.65	21.00	0
8	85.74	61.00	0	40	31.23	23.00	0
9	53.90	82.00	0	41	0.45	0.00	0
10	0.00	0.00	2	42	16.67	0.00	4
11	53.00	66.00	0	43	27.63	0.00	4
12	57.06	47.00	0	44	36.79	31.00	0
13	45.20	45.00	0	45	19.67	18.00	0
14	52.70	34.00	0	46	11.56	7.00	0
15	65.02	20.00	0	47	10.66	0.00	4
16	46.10	0.00	4	48	0.60	0.00	0
17	54.95	0.00	4	49	0.03	0.00	4
18	48.80	0.00	4	50	13.96	0.00	4
19	62.76	0.00	4	51	23.72	0.00	4
20	44.74	19.00	0	52	28.08	0.00	4
21	25.83	21.00	0	53	18.02	0.00	4
22	13.36	23.00	0	54	22.37	0.00	4
23	50.15	21.00	0	55	25.98	11.00	0
24	53.45	0.00	4	56	30.18	0.00	4
25	3.30	28.00	0	57	12.01	0.00	4
26	30.93	0.00	4	58	0.45	0.00	0
27	25.68	0.00	4	59	2.70	0.00	0
28	25.23	0.00	4	60	12.46	0.00	0
29	28.98	0.00	4	61	0.00	0.00	0
30	2.85	0.00	4	62	1.05	0.00	0
31	35.74	0.00	4	63	1.18	0.00	0
32	67.42	7.00	0	64	2.10	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.12 OLB33-2

OLB33-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	56.61	31.00	0	33	45.80	0.00	4
2	31.68	46.00	0	34	46.85	19.00	0
3	59.16	51.00	0	35	1.95	0.00	4
4	49.85	59.00	0	36	40.54	0.00	1
5	21.47	56.00	0	37	9.46	0.00	4
6	75.38	42.00	0	38	19.82	0.00	4
7	66.67	35.00	0	39	9.31	0.00	4
8	62.31	54.00	0	40	31.98	0.00	4
9	49.70	61.00	0	41	6.46	0.00	4
10	0.00	0.00	2	42	0.00	0.00	4
11	51.05	33.00	0	43	27.03	0.00	4
12	66.97	42.00	0	44	54.95	8.00	0
13	53.30	47.00	0	45	61.26	22.00	0
14	63.71	32.00	0	46	42.34	24.00	0
15	3.30	0.00	0	47	45.95	21.00	0
16	41.74	0.00	4	48	66.67	6.00	0
17	24.77	32.00	0	49	60.96	29.00	0
18	27.33	31.00	0	50	73.72	31.00	0
19	47.60	0.00	5	51	62.61	24.00	0
20	50.15	35.00	0	52	62.46	34.00	0
21	40.54	23.00	0	53	84.08	30.00	0
22	46.55	13.00	0	54	86.19	24.00	0
23	53.15	13.00	0	55	7.66	0.00	0
24	51.80	14.00	0	56	81.98	0.00	0
25	51.05	18.00	0	57	25.38	19.00	0
26	33.03	21.00	0	58	55.86	13.00	0
27	69.82	14.00	0	59	84.23	26.00	0
28	58.11	16.00	0	60	72.97	47.00	0
29	37.09	18.00	0	61	66.97	21.00	0
30	29.58	22.00	0	62	76.73	36.00	0
31	40.09	21.00	0	63	67.27	36.00	0
32	54.35	17.00	0	64	80.33	20.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.13 OLB33-6

OLB33-6
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	18.77	6.00	0	33	10.21	0.00	0
2	35.89	7.00	0	34	44.14	8.00	0
3	34.38	11.00	0	35	3.15	0.00	0
4	33.03	13.00	0	36	3.75	0.00	0
5	36.19	19.00	0	37	0.90	0.00	0
6	48.05	13.00	0	38	45.80	14.00	0
7	34.08	13.00	0	39	26.88	6.00	0
8	50.45	12.00	0	40	29.58	0.00	0
9	25.83	13.00	0	41	3.30	0.00	0
10	0.00	0.00	2	42	6.61	0.00	0
11	45.80	23.00	0	43	4.20	0.00	0
12	47.75	15.00	0	44	22.97	5.00	0
13	34.23	13.00	0	45	4.20	0.00	0
14	28.83	15.00	0	46	5.11	0.00	0
15	28.08	12.00	0	47	44.59	19.00	0
16	43.24	17.00	0	48	6.01	0.00	0
17	44.89	15.00	0	49	0.00	0.00	0
18	50.15	27.00	0	50	0.30	0.00	0
19	11.71	6.00	0	51	9.46	0.00	0
20	6.31	0.00	0	52	5.71	0.00	0
21	0.30	0.00	0	53	3.00	0.00	0
22	2.25	0.00	0	54	0.30	0.00	0
23	3.90	0.00	0	55	2.85	0.00	0
24	16.82	0.00	0	56	2.25	0.00	0
25	21.92	37.00	0	57	0.00	0.00	0
26	1.50	0.00	0	58	0.90	0.00	0
27	16.97	14.00	0	59	14.86	0.00	0
28	15.32	0.00	0	60	29.88	19.00	0
29	19.67	16.[illegible]	0	61	18.32	10.00	0
30	25.68	13.[illegible]	0	62	24.92	8.00	0
31	25.83	13.[illegible]0	0	63	16.22	10.00	0
32	44.86	32.[illegible]0	0	64	30.48	6.00	0

Exclusion Code [illegible]nd:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.14 OLB34-2

OLB34-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	28.53	0.00	4	33	9.16	0.00	4
2	56.31	17.00	0	34	55.11	28.00	0
3	73.57	32.00	0	35	68.02	38.00	0
4	66.52	31.00	0	36	89.79	44.00	0
5	75.83	31.00	0	37	72.22	48.00	0
6	83.63	50.00	0	38	36.19	0.00	5
7	85.29	43.00	0	39	85.74	51.00	0
8	79.43	43.00	0	40	67.27	15.00	0
9	73.42	21.00	0	41	55.14	0.00	4
10	0.00	0.00	2	42	71.77	12.00	0
11	90.84	47.00	0	43	92.94	57.00	0
12	84.98	55.00	0	44	85.29	42.00	0
13	60.51	67.00	0	45	68.02	36.00	0
14	68.02	44.00	0	46	72.22	35.00	0
15	53.30	40.00	0	47	64.26	40.00	0
16	52.40	40.00	0	48	70.72	16.00	0
17	77.78	39.00	0	49	0.30	0.00	0
18	85.44	26.00	0	50	1.20	0.00	0
19	64.41	36.00	0	51	3.60	0.00	0
20	78.38	30.00	0	52	7.66	0.00	0
21	76.28	0.00	5	53	1.05	0.00	0
22	63.21	61.00	0	54	48.80	15.00	0
23	48.65	15.00	0	55	70.87	51.00	0
24	64.71	35.00	0	56	54.65	0.00	5
25	60.36	36.00	0	57	42.19	0.00	5
26	49.40	26.00	0	58	54.05	27.00	0
27	60.66	0.00	5	59	73.72	64.00	0
28	61.56	33.00	0	60	56.61	23.00	0
29	46.85	33.00	0	61	30.78	22.00	0
30	35.41	44.00	0	62	46.10	23.00	0
31	74.47	56.00	0	63	80.93	51.00	0
32	42.04	66.00	0	64	72.97	54.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.15 OLB34-3

OLB34-3
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: high Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.44	0.00	0	33	0.00	0.00	0
2	78.38	38.00	0	34	0.30	0.00	0
3	69.52	17.00	0	35	46.55	28.00	0
4	76.58	34.00	0	36	28.98	14.00	0
5	90.69	40.00	0	37	60.81	31.00	0
6	84.68	31.00	0	38	75.08	41.00	0
7	58.41	34.00	0	39	47.90	17.00	0
8	87.54	37.00	0	40	23.12	11.00	0
9	43.54	35.00	0	41	32.13	44.00	0
10	0.00	0.00	2	42	49.10	50.00	0
11	60.96	29.00	0	43	58.41	38.00	0
12	59.16	44.00	0	44	83.78	47.00	0
13	17.57	0.00	3	45	10.06	0.00	3
14	31.08	34.00	0	46	5.71	0.00	0
15	33.03	30.00	0	47	12.16	0.00	0
16	28.83	15.00	0	48	5.56	0.00	0
17	75.83	41.00	0	49	3.75	15.00	0
18	3.90	9.00	0	50	50.00	14.00	0
19	90.39	43.00	0	51	40.54	13.00	0
20	91.74	28.00	0	52	6.31	5.00	0
21	0.75	0.00	0	53	57.36	32.00	0
22	48.05	28.00	0	54	1.50	0.00	0
23	70.12	44.00	0	55	46.55	20.00	0
24	54.35	44.00	0	56	62.61	43.00	0
25	68.02	44.00	0	57	59.31	32.00	0
26	0.30	6.00	0	58	43.54	14.00	0
27	71.47	45.00	0	59	69.67	41.00	0
28	84.23	44.00	0	60	70.72	43.00	0
29	65.32	43.00	0	61	30.03	18.00	0
30	58.11	25.00	0	62	30.78	23.00	0
31	4.95	14.00	0	63	40.24	18.00	0
32	67.87	44.00	0	64	18.17	22.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.16 OLB35-2

OLB35-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	9.61	0.00	0	33	0.30	0.00	0
2	15.02	0.00	0	34	9.16	0.00	0
3	14.26	0.00	0	35	3.00	0.00	0
4	17.87	0.00	0	36	79.13	0.00	5
5	5.86	0.00	0	37	76.28	93.00	0
6	16.07	0.00	0	38	74.62	49.00	0
7	10.96	0.00	0	39	92.94	96.00	0
8	3.75	0.00	0	40	93.54	79.00	0
9	5.11	0.00	0	41	0.60	0.00	0
10	0.00	0.00	2	42	80.03	100.00	0
11	76.73	39.00	0	43	85.14	49.00	0
12	23.27	0.00	0	44	77.33	48.00	0
13	6.46	0.00	0	45	74.32	61.00	0
14	18.92	0.00	0	46	76.28	70.00	0
15	17.12	0.00	0	47	77.18	75.00	0
16	16.82	0.00	0	48	15.17	0.00	0
17	0.00	0.00	0	49	71.92	36.00	0
18	6.46	0.00	0	50	76.43	45.00	0
19	12.61	0.00	0	51	71.92	64.00	0
20	37.09	0.00	0	52	68.62	66.00	0
21	4.05	0.00	0	53	80.48	64.00	0
22	8.11	0.00	0	54	68.77	36.00	0
23	2.55	0.00	0	55	68.62	50.00	0
24	3.75	0.00	0	56	87.69	40.00	0
25	0.60	0.00	0	57	60.21	0.00	0
26	1.05	0.00	0	58	78.23	26.00	0
27	2.55	0.00	0	59	88.14	84.00	0
28	4.05	0.00	0	60	54.05	70.00	0
29	0.00	0.00	0	61	71.62	62.00	0
30	59.76	54.00	0	62	18.02	0.00	0
31	0.60	0.00	0	63	66.22	50.00	0
32	50.15	82.00	0	64	91.14	56.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.17 OLB35-4

OLB35-4

64 position solder TAB (position 10 vacant)

Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:

Pressure: med Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	6.01	0.00	0	33	65.17	65.00	0
2	79.73	50.00	0	34	40.84	50.00	0
3	82.58	90.00	0	35	64.58	50.00	0
4	79.28	120.00	0	36	74.02	80.00	0
5	77.93	75.00	0	37	35.44	65.00	0
6	85.59	95.00	0	38	54.35	85.00	0
7	81.83	60.00	0	39	7.81	0.00	0
8	83.78	110.00	0	40	10.21	0.00	0
9	65.17	110.00	0	41	63.21	100.00	0
10	0.00	0.00	2	42	68.17	100.00	0
11	61.11	115.00	0	43	76.43	85.00	0
12	47.00	95.00	0	44	59.46	75.00	0
13	51.05	80.00	0	45	39.79	70.00	0
14	6.91	0.00	0	46	53.75	55.00	0
15	16.22	0.00	0	47	67.12	60.00	0
16	24.32	0.00	0	48	59.16	40.00	0
17	63.21	95.00	0	49	53.30	0.00	4
18	58.26	100.00	0	50	52.85	90.00	0
19	80.48	115.00	0	51	75.98	120.00	0
20	80.03	115.00	0	52	78.98	95.00	0
21	86.34	90.00	0	53	58.86	90.00	0
22	85.29	110.00	0	54	89.79	100.00	0
23	75.98	110.00	0	55	80.48	115.00	0
24	93.54	110.00	0	56	87.39	115.00	0
25	78.23	105.00	0	57	72.07	115.00	0
26	84.83	110.00	0	58	85.14	70.00	0
27	93.54	120.00	0	59	14.56	45.00	0
28	89.64	65.00	0	60	5.71	0.00	0
29	84.23	85.00	0	61	7.51	35.00	0
30	81.83	105.00	0	62	45.05	65.00	0
31	75.38	110.00	0	63	78.53	80.00	0
32	48.80	95.00	0	64	64.86	70.00	0

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.18 OLB35-6

OLB35-6
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	0	33	42.04	50.00	0
2	7.36	0.00	0	34	0.00	0.00	0
3	62.46	75.00	0	35	92.79	70.00	0
4	75.53	102.00	0	36	89.34	45.00	0
5	72.67	0.00	5	37	82.88	70.00	0
6	94.89	105.00	0	38	85.44	40.00	0
7	95.50	110.00	0	39	92.04	75.00	0
8	85.59	115.00	0	40	86.19	105.00	0
9	52.40	105.00	0	41	70.72	55.00	0
10	0.00	0.00	2	42	53.15	50.00	0
11	66.67	105.00	0	43	86.34	30.00	0
12	10.06	0.00	0	44	86.19	70.00	0
13	0.00	0.00	0	45	73.72	30.00	0
14	0.00	0.00	0	46	74.17	60.00	0
15	65.77	90.00	0	47	77.33	55.00	0
16	0.00	0.00	0	48	70.57	50.00	0
17	54.05	0.00	5	49	60.36	75.00	0
18	5.86	0.00	0	50	69.97	70.00	0
19	82.58	110.00	0	51	88.74	60.00	0
20	79.43	85.00	0	52	94.14	80.00	0
21	73.12	95.00	0	53	74.17	75.00	0
22	89.94	0.00	5	54	91.89	120.00	0
23	59.76	110.00	0	55	83.33	95.00	0
24	56.61	95.00	0	56	92.64	110.00	0
25	80.33	125.00	0	57	75.68	95.00	0
26	89.19	110.00	0	58	87.39	115.00	0
27	75.83	100.00	0	59	84.98	95.00	0
28	77.63	95.00	0	60	92.94	90.00	0
29	71.02	80.00	0	61	77.63	90.00	0
30	8.26	0.00	0	62	82.13	75.00	0
31	86.19	75.00	0	63	94.59	85.00	0
32	46.10	80.00	0	64	91.74	70.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.19 OLB36-2

OLB36-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	0	33	0.90	0.00	0
2	10.81	0.00	0	34	12.16	0.00	0
3	43.54	11.00	0	35	5.86	0.00	0
4	70.27	11.00	0	36	7.36	0.00	0
5	37.09	6.00	0	37	23.47	0.00	0
6	0.60	0.00	4	38	1.80	0.00	0
7	57.36	0.00	4	39	8.56	0.00	0
8	58.26	9.00	0	40	7.81	0.00	0
9	59.46	10.00	0	41	0.75	0.00	0
10	0.00	0.00	2	42	12.91	0.00	0
11	53.75	44.00	0	43	9.61	0.00	0
12	57.21	26.00	0	44	10.06	0.00	0
13	22.52	0.00	4	45	0.60	0.00	0
14	0.00	0.00	0	46	5.26	0.00	0
15	43.09	0.00	4	47	2.70	0.00	0
16	47.90	0.00	4	48	5.56	0.00	0
17	6.31	0.00	0	49	49.85	17.00	0
18	13.30	0.00	0	50	52.10	20.00	0
19	13.96	0.00	0	51	43.24	0.00	4
20	10.06	0.00	4	52	47.30	0.00	4
21	1.80	0.00	0	53	48.05	7.00	0
22	19.97	17.00	0	54	57.51	0.00	4
23	25.53	0.00	4	55	59.16	8.00	0
24	14.56	0.00	4	56	60.66	12.00	0
25	13.96	0.00	4	57	46.25	0.00	4
26	28.23	0.00	4	58	44.89	11.00	0
27	29.28	0.00	4	59	49.70	8.00	0
28	34.68	0.00	4	60	62.61	0.00	4
29	24.77	0.00	4	61	28.53	0.00	4
30	29.58	0.00	4	62	56.61	16.00	0
31	18.32	0.00	4	63	13.66	0.00	0
32	34.24	0.00	4	64	25.23	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kaptcn-affected leads

Table A.2.20 OLB36-4

OLB36-4
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	0.00	6	33	67.27	24.00	0
2	0.00	15.00	6	34	51.20	14.00	0
3	0.00	13.00	6	35	45.65	21.00	0
4	0.00	17.00	6	36	81.83	33.00	0
5	27.78	17.00	0	37	60.96	43.00	0
6	30.18	21.00	0	38	60.36	44.00	0
7	49.25	20.00	0	39	52.10	40.00	0
8	27.03	25.00	0	40	60.66	31.00	0
9	0.00	21.00	0	41	49.10	40.00	0
10	0.00	0.00	2	42	67.57	32.00	0
11	0.00	25.00	0	43	87.24	35.00	0
12	22.82	36.00	0	44	83.63	44.00	0
13	12.76	32.00	0	45	69.97	44.00	0
14	14.56	7.00	0	46	79.58	37.00	0
15	33.33	5.00	0	47	68.77	31.00	0
16	36.34	0.00	0	48	43.09	12.00	0
17	62.46	31.00	0	49	2.25	0.00	0
18	62.61	39.00	0	50	8.11	0.00	0
19	63.06	16.00	0	51	14.41	0.00	0
20	8.86	8.00	0	52	13.36	0.00	0
21	27.18	25.00	0	53	6.61	0.00	0
22	38.44	35.00	0	54	8.71	0.00	0
23	30.63	37.00	0	55	11.26	0.00	0
24	56.76	46.00	0	56	8.26	0.00	0
25	40.69	45.00	0	57	14.36	15.00	0
26	47.90	40.00	0	58	16.67	35.00	0
27	51.65	45.00	0	59	45.35	18.00	0
28	62.16	45.00	0	60	21.47	0.00	0
29	57.36	45.00	0	61	23.87	10.00	0
30	45.95	28.00	0	62	15.46	6.00	0
31	57.96	29.00	0	63	36.19	8.00	0
32	47.30	44.00	0	64	28.68	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.21 OLB37-2

OLB37-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med   Temperature: high   Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	11.26	0.00	0	33	45.50	0.00	4
2	9.91	0.00	0	34	5.11	0.00	0
3	13.81	0.00	0	35	0.60	0.00	4
4	45.20	0.00	0	36	16.37	0.00	4
5	3.90	0.00	0	37	59.01	14.00	0
6	61.71	11.00	0	38	61.26	8.00	0
7	15.47	0.00	0	39	78.68	0.00	4
8	23.72	0.00	0	40	1.50	0.00	0
9	7.96	0.00	0	41	0.90	0.00	0
10	0.00	0.00	2	42	3.30	0.00	0
11	9.61	0.00	0	43	40.09	10.00	0
12	10.96	0.00	0	44	52.10	10.00	0
13	1.50	0.00	0	45	2.25	0.00	0
14	21.91	0.00	0	46	5.71	0.00	0
15	2.85	0.00	0	47	30.78	0.00	0
16	12.16	0.00	0	48	38.89	0.00	0
17	33.63	0.00	4	49	75.53	7.00	0
18	56.61	15.00	0	50	76.88	11.00	0
19	61.41	18.00	0	51	49.70	0.00	4
20	79.73	28.00	0	52	35.74	0.00	4
21	63.21	27.00	0	53	0.30	0.00	4
22	54.20	22.00	0	54	8.11	0.00	4
23	62.31	29.00	0	55	2.85	0.00	4
24	40.84	0.00	4	56	14.86	0.00	4
25	62.76	42.00	0	57	3.45	0.00	4
26	73.72	14.00	0	58	55.26	0.00	4
27	66.97	0.00	4	59	60.66	6.00	0
28	88.29	24.00	0	60	63.06	0.00	4
29	48.95	26.00	0	61	68.77	12.00	0
30	72.07	6.00	0	62	73.42	8.00	0
31	72.67	11.00	0	63	94.44	11.00	0
32	35.89	0.00	4	64	77.78	0.00	4

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.22 OLB37-4

OLB37-4
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: high Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	3.30	0.00	0
2	4.80	0.00	0
3	8.71	0.00	0
4	13.96	0.00	0
5	12.61	0.00	0
6	21.02	0.00	0
7	1.80	0.00	0
8	9.70	0.00	0
9	7.21	0.00	0
10	0.00	0.00	2
11	1.35	0.00	0
12	19.67	0.00	0
13	8.26	0.00	0
14	18.62	0.00	0
15	12.01	0.00	0
16	21.02	0.00	0
17	22.22	0.00	0
18	24.32	7.00	0
19	26.28	7.00	0
20	47.90	9.00	0
21	33.63	7.00	0
22	40.84	11.00	0
23	40.54	10.00	0
24	29.73	9.00	0
25	30.48	8.00	0
26	43.24	14.00	0
27	57.96	14.00	0
28	35.14	10.00	0
29	28.68	9.00	0
30	24.17	5.00	0
31	16.97	5.00	0
32	2.10	0.00	0
33	3.45	0.00	0
34	10.21	0.00	0
35	12.61	0.00	0
36	8.71	0.00	0
37	1.80	0.00	0
38	5.56	0.00	0
39	18.77	0.00	0
40	0.00	0.00	0
41	1.20	0.00	0
42	22.22	6.00	0
43	17.57	5.00	0
44	32.58	5.00	0
45	24.02	9.00	0
46	19.97	5.00	0
47	22.67	5.00	0
48	22.22	6.00	0
49	20.12	9.00	0
50	46.70	23.00	0
51	1.35	0.00	9
52	4.65	0.00	9
53	5.26	0.00	9
54	14.26	0.00	9
55	3.45	0.00	9
56	10.51	0.00	9
57	8.56	0.00	9
58	42.04	40.00	0
59	16.67	0.00	9
60	40.24	40.00	0
61	8.71	0.00	9
62	18.92	33.00	0
63	11.41	0.00	9
64	28.53	0.00	9

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.23 OLB38-2

OLB38-2
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at GTE

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	37.39	0.00	4	33	10.81	0.00	0
2	82.58	0.00	4	34	44.74	0.00	1
3	70.12	0.00	4	35	87.24	8.00	0
4	68.77	8.00	0	36	90.84	12.00	0
5	53.90	9.00	0	37	41.74	0.00	4
6	80.78	10.00	0	38	93.24	19.00	0
7	92.94	16.00	0	39	9.46	0.00	4
8	78.98	13.00	0	40	26.88	0.00	4
9	0.00	0.00	0	41	1.65	0.00	4
10	0.00	0.00	2	42	78.23	30.00	0
11	45.95	10.00	0	43	74.47	22.00	0
12	0.30	0.00	0	44	76.73	17.00	0
13	1.95	0.00	0	45	64.26	0.00	5
14	4.50	0.00	0	46	88.14	13.00	0
15	3.30	0.00	0	47	81.08	0.00	4
16	3.15	0.00	0	48	3.60	0.00	0
17	31.23	0.00	4	49	51.20	10.00	0
18	58.26	0.00	4	50	53.90	16.00	0
19	3.75	0.00	0	51	3.30	0.00	0
20	11.26	0.00	0	52	2.55	0.00	0
21	48.65	0.00	4	53	2.70	0.00	0
22	51.35	0.00	4	54	41.44	13.00	0
23	39.64	7.00	0	55	5.51	0.00	0
24	19.37	0.00	4	56	5.56	0.00	0
25	56.91	13.00	0	57	5.26	0.00	0
26	5.41	0.00	0	58	7.21	0.00	0
27	14.41	0.00	0	59	9.31	0.00	0
28	5.71	0.00	0	60	8.41	0.00	0
29	17.12	0.00	0	61	0.00	0.00	0
30	23.12	0.00	0	62	34.68	0.00	1
31	15.17	0.00	0	63	1.65	0.00	0
32	13.06	8.00	0	64	14.86	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.24 OLB38-5

OLB38-5
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: med

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	2.55	0.00	0
2	6.46	0.00	0
3	33.48	17.00	0
4	9.31	0.00	0
5	50.15	17.00	0
6	64.11	33.00	0
7	11.26	0.00	0
8	12.76	0.00	0
9	0.90	9.00	0
10	0.00	0.00	2
11	2.40	0.00	0
12	41.89	10.00	0
13	3.15	0.00	0
14	26.88	5.00	0
15	2.25	0.00	0
16	1.50	0.00	0
17	62.01	16.00	0
18	48.65	18.00	0
19	52.70	29.00	0
20	67.42	33.00	0
21	6.61	0.00	0
22	4.50	0.00	0
23	31.53	31.00	0
24	61.55	38.00	0
25	59.61	44.00	0
26	23.12	34.00	0
27	56.16	47.00	0
28	52.55	38.00	0
29	25.08	7.00	0
30	21.92	8.00	0
31	4.20	0.00	0
32	3.15	0.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
33	44.29	8.00	0
34	47.45	9.00	0
35	4.05	0.00	0
36	48.50	31.00	0
37	41.74	43.00	0
38	52.70	38.00	0
39	54.95	43.00	0
40	51.50	46.00	0
41	24.47	45.00	0
42	69.97	42.00	0
43	24.02	21.00	0
44	7.51	0.00	0
45	49.70	30.00	1
46	51.80	44.00	1
47	39.04	27.00	1
48	22.67	8.00	0
49	0.00	0.00	0
50	72.07	33.00	0
51	43.24	13.00	0
52	23.57	0.00	1
53	3.75	0.00	0
54	8.86	21.00	0
55	42.19	31.00	0
56	65.02	44.00	0
57	4.35	15.00	0
58	11.26	27.00	0
59	19.37	32.00	0
60	51.35	20.00	0
61	48.20	28.00	0
62	10.36	11.00	0
63	13.66	8.00	0
64	46.85	20.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.2.25 OLB39-4

OLB39-4
64 position solder TAB (position 10 vacant)
Outer-Lead Bond Pull Test Performed at Sonoscan

Bonding Conditions Applicable:
Pressure: med Temperature: med Time: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	9.01	0.00	0	33	2.40	0.00	0
2	8.86	0.00	0	34	0.60	0.00	0
3	22.37	0.00	0	35	1.20	0.00	0
4	7.66	0.00	0	36	33.78	13.00	0
5	5.41	0.00	0	37	5.11	13.00	0
6	36.64	0.00	0	38	15.62	0.00	4
7	20.57	0.00	0	39	0.75	0.00	0
8	33.63	0.00	0	40	2.40	0.00	0
9	17.27	0.00	0	41	1.20	0.00	0
10	0.00	0.00	2	42	0.00	0.00	0
11	62.61	20.00	0	43	50.45	13.00	0
12	56.31	19.00	0	44	45.35	12.00	0
13	28.98	13.00	0	45	14.86	8.00	0
14	48.65	14.00	0	46	41.14	10.00	0
15	37.69	8.00	0	47	3.60	0.00	4
16	27.93	0.00	0	48	3.15	0.00	4
17	37.84	0.00	0	49	7.06	0.00	4
18	12.46	0.00	0	50	9.61	0.00	4
19	5.86	0.00	0	51	0.00	0.00	4
20	10.21	0.00	0	52	0.00	0.00	4
21	4.95	0.00	0	53	0.45	0.00	4
22	22.82	7.00	0	54	3.00	0.00	4
23	13.66	0.00	0	55	0.00	0.00	4
24	20.42	0.00	0	56	11.86	0.00	4
25	2.10	0.00	0	57	1.65	0.00	4
26	9.46	0.00	0	58	6.61	0.00	4
27	14.71	0.00	0	59	13.36	0.00	4
28	23.42	0.00	0	60	9.31	0.00	4
29	1.50	0.00	0	61	0.00	0.00	4
30	8.56	0.00	0	62	0.00	0.00	4
31	29.13	19.00	0	63	0.00	0.00	4
32	44.89	19.00	0	64	0.00	0.00	4

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.3 MESA ILB Samples

MESA ILB (AuAu & AuSn TAB)

BONDING CONDITIONS: pres. & comp.

Sample#	SLAM Bond% max val	SLAM Bond% raw avg	SLAM Bond% avg. w/exc	GRAMS Pull max val	GRAMS Pull raw avg	GRAMS Pull avg. w/exc	# of exclusions w/codes 2-9	dominant exclusion code	pull tested by	BONDING CONDITIONS: pres. & comp.
ILB-A-1	100.00	55.68	55.68	64.30	41.24	41.24	0	0	SS	M AuAu
ILB-B-1	99.21	74.67	74.67	64.90	50.27	50.27	0	0	SS	H AuAu
ILB-C-1	98.41	76.73	76.40	51.60	36.44	36.92	1	5	SS	M AuSn
ILB-D-1	100.00	85.96	85.96	46.50	38.41	38.41	0	0	SS	H AuSn
ILB-E-1	75.79	26.06	26.06	49.50	11.56	11.56	0	0	SS	L AuAu
ILB-F-1	69.44	15.19	15.19	39.20	3.75	3.75	0	0	SS	L AuSn

Exclusion Code Legend:

0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.3.1 ILB-A-1

ILB-A-1
68 position Au-Au MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: med

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	3.60	0	35	77.38	64.10	0
2	0.00	0.00	0	36	81.75	58.10	0
3	13.49	20.60	0	37	84.13	56.40	0
4	0.00	23.20	0	38	82.14	56.10	0
5	40.87	26.50	0	39	94.84	61.00	0
6	46.83	31.30	0	40	96.83	57.70	0
7	43.65	40.30	0	41	96.03	60.30	0
8	82.14	55.10	0	42	97.62	54.20	0
9	45.24	54.30	0	43	96.03	53.30	0
10	73.41	43.10	0	44	94.44	59.00	0
11	74.21	53.90	0	45	69.05	58.30	0
12	70.24	55.50	0	46	63.10	46.80	0
13	74.21	48.60	0	47	64.29	52.60	0
14	71.43	48.30	0	48	70.24	64.30	0
15	81.75	38.70	0	49	45.63	62.00	0
16	73.81	17.50	0	50	61.51	55.40	0
17	71.83	6.70	0	51	72.22	53.10	0
18	7.54	23.60	0	52	1.19	1.70	0
19	23.02	36.10	0	53	69.44	50.80	0
20	23.81	49.80	0	54	78.97	58.30	0
21	17.46	54.10	0	55	0.00	0.00	0
22	43.25	54.80	0	56	89.68	61.20	0
23	51.98	52.00	0	57	3.17	1.80	0
24	53.97	49.40	0	58	100.00	61.00	0
25	0.00	0.00	0	59	65.87	55.10	0
26	58.33	12.10	0	60	78.17	53.00	0
27	63.10	51.30	0	61	69.44	53.20	0
28	0.00	2.30	0	62	71.03	47.60	0
29	68.65	46.50	0	63	78.57	53.60	0
30	74.21	41.20	0	64	84.52	45.10	0
31	71.43	36.40	0	65	59.92	47.60	0
32	0.00	2.60	0	66	65.48	52.40	0
33	0.00	0.00	0	67	57.14	47.40	0
34	46.43	43.60	0	68	0.00	23.80	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB-B-1
68 position Au-Au MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	47.22	33.50	0	35	66.67	55.60	0
2	63.10	41.00	0	36	88.10	59.10	0
3	62.30	43.30	0	37	84.92	56.80	0
4	69.44	47.50	0	38	85.71	59.20	0
5	56.75	51.40	0	39	70.24	55.80	0
6	68.65	57.40	0	40	75.40	56.90	0
7	57.54	59.70	0	41	77.78	56.20	0
8	75.40	64.90	0	42	88.10	56.80	0
9	85.32	60.50	0	43	85.32	58.20	0
10	82.54	56.10	0	44	90.87	57.60	0
11	78.57	51.70	0	45	54.76	19.20	0
12	69.44	57.10	0	46	85.71	50.50	0
13	74.60	60.50	0	47	82.14	58.60	0
14	67.86	52.40	0	48	61.90	52.20	0
15	70.63	61.10	0	49	83.73	56.80	0
16	77.78	57.50	0	50	84.52	56.00	0
17	45.24	49.60	0	51	87.30	60.70	0
18	71.03	52.30	0	52	99.21	59.20	0
19	76.19	50.30	0	53	97.22	51.30	0
20	82.94	48.60	0	54	21.83	1.20	0
21	80.95	49.70	0	55	99.21	59.90	0
22	96.83	53.90	0	56	14.68	13.20	0
23	93.65	55.30	0	57	0.00	13.30	0
24	90.48	60.40	0	58	1.59	1.80	0
25	96.03	51.60	0	59	5.95	1.50	0
26	89.68	54.60	0	60	97.22	58.80	0
27	94.84	59.90	0	61	90.87	57.30	0
28	97.62	51.90	0	62	95.24	53.00	0
29	87.70	53.90	0	63	97.62	53.20	0
30	91.27	47.80	0	64	98.02	59.00	0
31	95.63	53.00	0	65	91.27	58.10	0
32	66.67	49.70	0	66	68.25	59.60	0
33	93.65	45.80	0	67	62.70	54.00	0
34	84.13	50.90	0	68	41.67	42.70	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.3.3 ILB-C-1

ILB-C-1
68 position Au-Sn MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: med

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	57.54	0.00	0
2	86.51	36.00	0
3	89.68	39.80	0
4	80.90	35.40	0
5	82.14	35.50	0
6	98.41	4.00	5
7	90.87	33.80	0
8	84.13	51.60	0
9	76.59	34.80	0
10	96.43	35.20	0
11	74.60	34.80	0
12	83.33	33.90	0
13	68.25	33.80	0
14	32.14	30.60	0
15	40.08	34.20	0
16	54.76	34.90	0
17	40.08	36.20	0
18	32.94	38.70	0
19	42.46	35.80	0
20	54.76	36.30	0
21	72.22	39.10	0
22	80.56	41.10	0
23	82.94	42.40	0
24	78.97	31.90	0
25	63.49	32.60	0
26	63.10	30.80	0
27	74.21	31.60	0
28	55.16	31.70	0
29	75.00	38.10	0
30	80.66	29.20	0
31	78.17	31.20	0
32	74.60	36.60	0
33	78.57	34.30	0
34	78.17	31.30	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
35	86.51	41.40	0
36	79.76	36.90	0
37	78.17	41.10	0
38	79.37	40.10	0
39	76.59	42.70	0
40	76.98	40.90	0
41	73.81	42.00	0
42	88.46	42.00	0
43	81.75	39.60	0
44	75.40	40.20	0
45	61.90	42.90	0
46	57.54	42.80	0
47	68.65	37.90	0
48	92.06	43.90	0
49	89.68	41.00	0
50	80.95	45.60	0
51	91.67	38.20	0
52	79.76	14.90	0
53	86.11	38.80	0
54	88.49	44.00	0
55	82.86	43.70	0
56	91.67	41.00	0
57	86.51	37.20	0
58	92.46	44.40	0
59	94.84	41.60	0
60	94.05	41.00	0
61	80.16	43.90	0
62	92.86	38.30	0
63	93.25	40.20	0
64	79.37	42.40	0
65	89.68	39.40	0
66	75.79	38.80	0
67	88.10	36.30	0
68	79.76	15.60	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

ILB-D-1
68 position Au-Sn MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: high

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.00	9.00	0	35	89.29	35.10	0
2	68.65	30.00	0	36	92.06	42.60	0
3	60.32	34.60	0	37	97.22	44.60	0
4	60.71	38.20	0	38	97.62	44.20	0
5	90.48	38.40	0	39	94.44	41.10	0
6	85.71	36.50	0	40	5.56	26.50	0
7	91.27	38.80	0	41	86.51	42.40	0
8	94.84	41.00	0	42	96.03	45.70	0
9	96.03	36.30	0	43	90.48	44.40	0
10	97.62	35.60	0	44	95.63	46.50	0
11	92.86	39.90	0	45	73.41	45.40	0
12	95.24	39.90	0	46	85.32	40.60	0
13	94.84	41.00	0	47	34.52	36.00	0
14	87.70	40.60	0	48	76.98	39.40	0
15	86.90	34.70	0	49	84.92	43.50	0
16	87.30	38.00	0	50	84.52	37.60	0
17	78.97	43.60	0	51	86.51	39.40	0
18	79.37	41.40	0	52	98.41	43.90	0
19	82.14	36.50	0	53	95.24	17.20	0
20	93.65	40.30	0	54	94.05	39.50	0
21	97.22	34.60	0	55	97.22	42.90	0
22	89.29	37.60	0	56	97.62	31.80	0
23	88.49	43.90	0	57	99.60	39.30	0
24	86.11	39.90	0	58	99.60	41.40	0
25	94.44	35.60	0	59	98.41	41.90	0
26	94.84	27.40	0	60	98.81	42.80	0
27	97.82	38.60	0	61	99.60	43.60	0
28	100.00	39.70	0	62	91.67	42.70	0
29	99.21	38.90	0	63	84.92	34.20	0
30	95.63	35.20	0	64	90.48	40.50	0
31	99.60	39.70	0	65	97.22	41.90	0
32	90.48	34.20	0	66	60.71	35.70	0
33	76.59	35.30	0	67	81.35	40.70	0
34	88.10	38.00	0	68	66.67	44.20	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.3.5 ILB-E-1

ILB-E-1
68 position Au-Au MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: low

Pos#	SLAM Bond%	GRAMS pull	exc. code
1	0.79	0.00	0
2	1.19	0.00	0
3	0.79	0.00	0
4	0.00	0.00	0
5	0.00	0.00	0
6	0.00	0.00	0
7	0.00	0.00	0
8	0.00	0.00	0
9	0.00	0.00	0
10	0.00	0.00	0
11	0.00	0.00	0
12	5.16	0.00	0
13	0.40	0.00	0
14	0.00	0.00	0
15	0.40	0.00	0
16	0.40	0.00	0
17	1.19	0.00	0
18	18.25	0.00	0
19	22.22	0.00	0
20	11.11	0.00	0
21	8.73	0.00	0
22	0.00	0.00	0
23	62.30	25.30	0
24	0.00	10.90	0
25	56.75	32.00	0
26	61.11	27.30	0
27	34.13	25.70	0
28	75.00	46.30	0
29	65.08	49.50	0
30	53.97	34.30	0
31	54.37	34.50	0
32	69.44	32.50	0
33	48.41	24.00	0
34	4.76	0.00	0

Pos#	SLAM Bond%	GRAMS pull	exc. code
35	27.78	0.00	0
36	41.67	0.00	0
37	44.44	0.00	0
38	45.63	0.00	0
39	54.76	28.70	0
40	62.30	22.40	0
41	51.19	33.60	0
42	47.62	30.70	0
43	51.19	20.80	0
44	53.57	17.80	0
45	0.79	0.00	0
46	1.59	0.00	0
47	0.40	0.00	0
48	0.00	0.00	0
49	1.19	0.00	0
50	5.95	0.00	0
51	2.78	0.00	0
52	0.40	0.00	0
53	35.32	0.00	0
54	55.16	25.70	0
55	57.14	27.10	0
56	56.35	37.00	0
57	66.27	40.80	0
58	69.05	44.60	0
59	65.48	42.90	0
60	75.79	34.50	0
61	67.06	37.20	0
62	4.76	0.00	0
63	7.14	0.00	0
64	5.95	0.00	0
65	4.76	0.00	0
66	5.16	0.00	0
67	0.30	0.00	0
68	0.00	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Table A.3.6 ILB-F-1

ILB-F-1
68 position Au-Sn MESA TAB
Inner-Lead Bond Pull Test Performed at MESA

Bonding Conditions Applicable:
Pressure: low

Pos#	SLAM Bond%	GRAMS pull	exc. code	Pos#	SLAM Bond%	GRAMS pull	exc. code
1	6.75	0.00	0	35	61.51	0.00	0
2	10.32	0.00	0	36	29.76	0.00	0
3	11.90	0.00	0	37	41.67	0.00	0
4	5.56	0.00	0	38	18.65	0.00	0
5	7.14	0.00	0	39	69.44	0.00	0
6	9.52	0.00	0	40	41.27	21.00	0
7	1.59	0.00	0	41	61.51	0.00	0
8	1.98	0.00	0	42	66.67	0.00	0
9	7.54	0.00	0	43	63.10	0.00	0
10	2.38	0.00	0	44	14.21	0.00	0
11	2.78	0.00	0	45	2.78	0.00	0
12	5.95	0.00	0	46	4.37	0.00	0
13	18.65	0.00	0	47	3.97	0.00	0
14	4.76	0.00	0	48	5.16	0.00	0
15	9.92	0.00	0	49	4.76	0.00	0
16	21.83	0.00	0	50	2.38	0.00	0
17	3.97	0.00	0	51	4.76	0.00	0
18	3.97	0.00	0	52	1.19	0.00	0
19	1.19	0.00	0	53	0.79	0.00	0
20	5.56	0.00	0	54	0.00	0.00	0
21	7.14	0.00	0	55	3.97	0.00	0
22	2.38	0.00	0	56	46.43	0.00	0
23	1.19	0.00	0	57	52.38	26.30	0
24	4.76	0.00	0	58	47.62	30.50	0
25	2.78	0.00	0	59	3.17	0.00	0
26	0.40	0.00	0	60	0.00	0.00	0
27	0.40	0.00	0	61	5.95	0.00	0
28	44.44	39.20	0	62	0.79	0.00	0
29	18.65	37.10	0	63	1.19	0.00	0
30	37.70	38.90	0	64	0.00	0.00	0
31	38.89	27.60	0	65	0.40	0.00	0
32	53.17	34.10	0	66	1.59	0.00	0
33	1.98	0.00	0	67	2.38	0.00	0
34	5.16	0.00	0	68	6.75	0.00	0

Exclusion Code Legend:
0) accepted data point
1) arbitrarily suspicious point
2) not a real pin...vacant
3) pull tester didn't reset
4) known prior damage/handling
5) pull tester didn't record
6) unstored/unreadable SLAM
7) solder-bridged leads
8) pad lift (prior to pull?)
9) kapton-affected leads

Contents: Appendix "B" Section 1

- Tensile versus Shear Strength
  - Ideal area-defined tensile failure
  - Band-defined tensile failure
  - Examples of wide- and narrow-bands at zone of tensile failure.

- Pull-test machine properties
  - Mass-and-Spring model
  - Hook sh e
  - Tweezers

- The effect of a "dog-leg" or "jog"
  - Development of Torque on the lead.
  - Pertinence to "corner effect"

- Other effects periodic to a revolution around the die perimeter
  - Milder corner effects in OLB's
  - Possible Thermode-Tilt effect in ILB's
  - Possible Intrinsic Corner and/or Tilt effect (not pull-test-related but fabrication-related) in MESA samples.

TENSILE VERSUS SHEAR STRENGTH

At first look, a pull test appears to measure the tensile strength of a bond area. If the pull were to be strictly along the axis of the lead, then in fact it would be the shear strength of the bond which would be tested. If the lead were quite rigid (inelastic), then the load would be distributed in shear quite well across the entire bond.

Conversely, to perform a true test of tensional strength, the tension would have to be distributed over the entire area of the bond. This is not practical for this arrangement, as no easy means exists for connecting the lead in this areal manner.

The pull tests are therefore more of a "peel" test. Depending upon the curvature radius of the lead, the actual rupture area is concentrated in a zone across the lead. (the length of the rupture zone is along an axis through the plane of the diagram; its width is shown in brackets). Force largely tensional, with some shear.

If the lead is caused to be more sharply bent, the effective force is concentrated into a narrower band, thereby putting effectively more force per unit area; in fact, the force applied, as measured at the source, becomes less, since it will more easily rupture the bond when so concentrated, and thus the bond acts as "regulator" by yielding progressively.

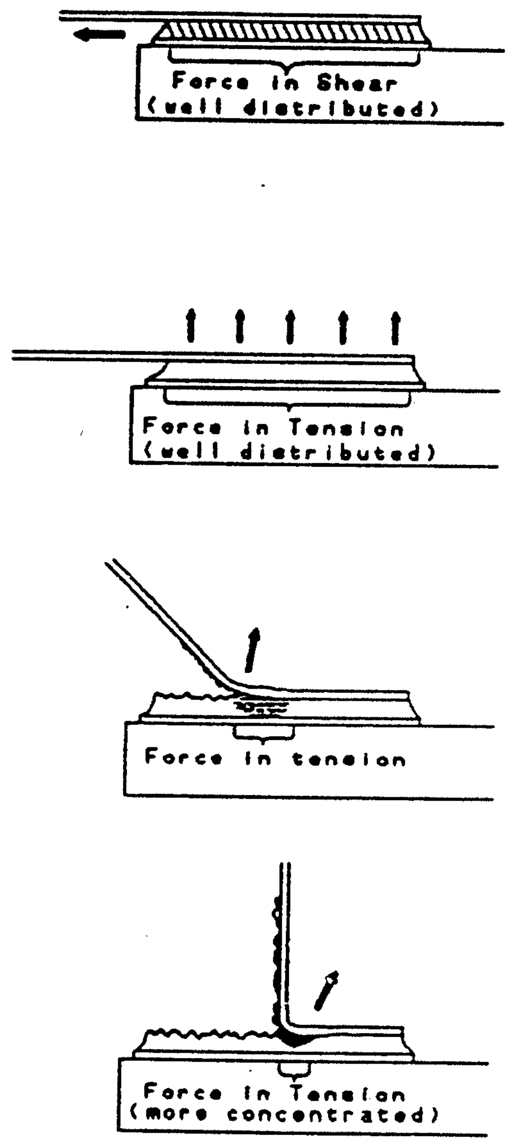
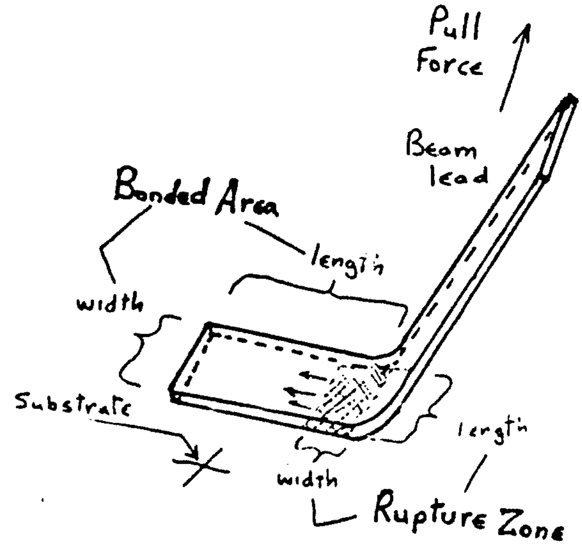


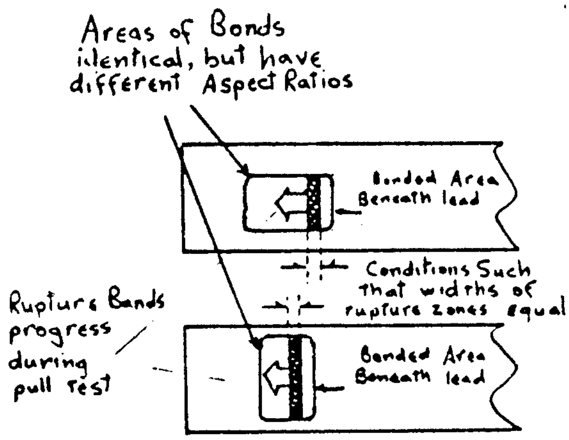
Figure B.1.1 Various Forces on Bond

The ideal area-defined tensile failure, as indicated above, is not easily capable of being provoked in TAB bonded samples, because of the essential difficulty in applying the force to the lead in the correct fashion. Other reasons include the fact that the material itself is not a pure crystal, but a randomly oriented cluster of crytalline and glassy elements (Due to the pressure factor in the bonding process, and to anisotropic crystal growth mitigated by surface factors, the orientation is not completely random). When such an effectively composite material begins to yield, strain is concentrated in some regions, and spread in others; a complex evolution of the fracture occurs. This evolution can be made to proceed in many different ways, depending upon the minute details of the application of the force, including its physical pattern, magnitude, rate, and direction. If the material were monocrystalline then it would yield briefly, nearly instantaneously, in a regular pattern as the result of the failure, at a single weakest point at its elastic limit. Instead, due to a combination of inelastic and elastic deformations, plastic flow, crystal cleavage, various dislocations, brittle fracture, and other effects, much more complex fracture systems occur.

The same holds true, but with additional degrees of freedom, when a pull test is conducted in the practical world, wherein there is a measure of progressive "peeling" as discussed above. Now, there is a BAND of rupture; its length is determined by the width of the bond area; its width is determined by many factors, including the flexibility of the lead, and the rate at which the lead is bent to an equilibrium curvature. Experimental factors which alter any of these variables can make significant changes in the perceived bond strength. The result is that the same bond, if it could magically be restored to the exact same initial condition after each of many pull tests, would give significantly different apparent strengths at each of those tests if the physical conditions of the test were altered in certain "apparently minor" ways. Conversely, it can be said that: 1) a given bond does not really have a single, "true" strength; and 2) certain experimental factors are not as "minor" as they might appear. The pursuit of a pull test to determine the one "true" strength of the bond against which other tests might be compared is therefore an arguable endeavor. Yet, if it is accepted that an individual pull test result is intrinsically subject to an amount of deviation from its most likely value, and if results are evaluated statistically rather than pointillistically, then a pull test can be of value. Nonetheless, the not-so-"minor" factors in the pull test must be: limited in extent by careful methodology; and, to whatever extent they remain, their effects recognized and analyzed. It may not be possible to predict all factors prone to cause significant variability prior to performing the tests, thus making it impossible to specify a regimen certain to alleviate all such effects. This puts the burden more squarely on the post-test analysis. As a result of the analysis, however, it becomes easier to formulate future tests that preserve the soundness of the data.

The strength of the bond relates to the area of the bond actually undergoing rupture at any given time. The zone of rupture moves along the bond as rupture proceeds, and the peak force registered for the bond is the largest force encountered over the time of the test. Thus the peak force is NOT proportional to bond area.



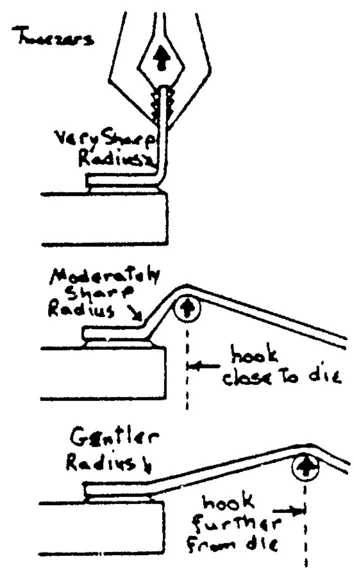


The shape as well as the area of the bond is important. If two bonds are of equal area, they do not necessarily show the same strength, depending upon the direction of rupture with respect to orientation of the broadest dimension of the bonded area.

Figure B.1.2 **Rupturing of a Bond (multiple sketches)**

The "attack angle" is of significance. Tweezers pull straight up, causing the sharpest bend in the lead, therefore concentrating the force most narrowly within the bond. This causes easier rupture at lowest absolute force.

The hook can never quite achieve the same orthogonal pull of the tweezers. The effect can be similar if the hook is as close to the bond as possible. If the hook is much farther away, the vector component pointed upward is less, and the sharpness of curvature and hence the concentration of force is less, making bond appear stronger.



An important realization is that pull strength of the bond is NOT proportional to the area of the bond. Rather, in the case where a "peeling" effect occurs (thus, in any regular pull test), strength is effectively proportional to the rupture area, which may be only small fraction of the bond area. Rupture area in turn is equal to the length of the rupture zone (taken as the dimension perpendicular to the direction of rupture), multiplied by the width of the rupture zone (width of the band undergoing current rupture, affected by the radius of the lead, as depicted above). Since the bond failure happens progressively, as the band moves, then if the band maintains a uniform width, peak force may be dictated only by the length of the rupture zone; i.e. width of bond across which the rupture band progresses. So, while the strength of a bond relates to a two-dimensional space (an area), it is not literally the area of the entire bond itself, but that of whatever portion is made to bear the load under the conditions of the destructive test. A number of considerations arise from this realization:

1) The proximity of the hook to the die may be important, as a controlling factor of the radius of the lead near the bond, and hence the width of the rupture zone.
2) The speed of the pull may be important, as it may control the radius of the lead, owing to a finite relaxation time of the presumably stiffer metal, affecting width, thus strength.
3) Variations in the thickness of the leads themselves may effect changes in the bend radius near the bond, and hence affect the width of the rupture zone, and hence its strength.
4) Non-uniformities in the width-vs-length ratio of the bond area may effect apparent pull strength, yet leave the SLAM-measured area constant, causing some intrinsic variance in interpretation.
5) ANY OTHER factor which causes a geometric effect near the bonding pad, especially those effects which alter the width of the rupture zone, will affect the apparent pull strength.

The reason these factors are important reduces to the fact that FORCE and WORK are not the same quantity. That these could easily be confused is made all the more evident by considering the "mild" error made consistently along the vertical axes of the data graphs in the first appendix. They are all labelled in "GRAMS", which as students of physics know, is not a measure of FORCE at all, but is a measure of MASS, or quantity of matter. That there exists somewhere an amount of matter, be it lead or helium, does not put any FORCE upon the leads in the pull test regimen. Obviously, what is meant is that a FORCE is registered which would be equivalent to that exerted upon such a MASS, in the given gravitational field. This discrepancy should not be taken lightly; it totally confusticates any attempt at doing dimensional analysis of poorly composed equations. Furthermore, just such a discrepancy, due to a lack of discrimination between FORCE and WORK, may cause erroneous interpretation of the present data, and a failure to understand how the results may so easily vary

from one's strictest expectations.

A useful depiction of the situation is the following: Consider a chain of high strength which links a series of plates. Each plate is individually cemented in place to a rigid structure, such as a concrete floor. By pulling upon the chain, one intends that the plates all be removed from the floor. The chain is connected to a device which measures and holds the peak force applied. Pulling is begun, and the first plate breaks off, fracturing the bond at some level of force, which is recorded and held by the instrument. Then each subsequent plate is also removed. Some will release at lower forces, and will not change the reading. Some may release at some slightly higher force, and the instrument will thus be caused to store that new, slightly higher value. At the end of the test, it will read the peak value required. If all the plates had been in parallel, rather than in series, they would have simultaneously contributed their strength, and the total peak force would be made to read much higher; it would then be approximately equal to the number of plates times the force of the average plate. Conversely, had the plates been made much smaller, but more numerous, then the peak force registered would be proportionately smaller. In each case, the total amount of work done to remove all plates would be effectively identical. Yet, the peak force registered in each case varies considerably.

The proximity of the hook to the die is important because it dictates the "attack angle" of the lead with respect to the bond area being ruptured. This angle, in conjunction with the pliability of the lead itself, determines the radius of curvature of the lead at the site of the rupture, and thus the effective width of the band of rupturing material. This in turn determines the force that is required to sustain the rupture.

The speed of the pull may be significant in that there may be some relaxation time constant for the bending of the (presumably stiff) lead material. If the pull is slow enough that the flexure of the lead can keep pace with the progresss of rupturing, then the maximum concentration of force (mimimum curvature radius of the lead) will be sustained per area of rupture, thereby leading to a lower applied force for rupture. Conversely, if the lead cannot relax to its tightest equilibrium curvature during the course of a rapid pull, then a wider rupture band will be caused, requiring a higher absolute applied force to cause rupture. This higher force also acts, in a feed-back mechanism, to tend to augment the flexure of of the lead, but only within the constraints of the time constant of relaxation of the lead, if the force is applied rapidly enough.

The thickness and specific mechanical properties of each lead can vary. Particularly, differences in strength and flexibility due to plating characteristics and thermal history can be pronounced in such thin materials, where the thickness of the lead is on the order of any plating that may be present, and also on the order of its microcrystalline structure. Therefore, there is expected to be variation in the radius of curvature of neighboring leads, and perhaps more so between those of different samples.

The aspect ratio of the bond area itself is important. Different aspect ratios

can have identical bond areas, as read by a method capable of determining these areas, such as SLAM. Because a force is applied over a narrower rupture band in one sample, albeit for a longer time, the peak force to cause rupture will be a lower one than for another sample with a more broad aspect ratio. Although both bonds may have high integrity, and both give suitably high pull test values, the noticeable disparity in their pull tests, as seen against the bond area equality shown by the other method, may unfairly question the consistency of that other method, when in fact the pull tests themselves inconsistently represent the value of the bond area by rendering differing values, due to geometric influences, upon the yield strength of otherwise equal-area bonds. One might, in haste, forget that failures in real service do not occur by the hook-pulling of a lead at such an angle with respect to the die, and that therefore the specific geometric influences of the pull-test are prejudicial.

Other factors which change the effective width of the rupture zone can be important. It was found that some such factor must be in effect near the corners of the die, most especially when performing pull tests on the ILB samples. A discussion of this factor is to follow further below.

PULL-TEST MACHINE PROPERTIES

The basic pull test machine consists of means of generating force along a given line of motion, a method of recording the peak value of that force, and a means of communicating that force to the test object. Hidden within these formal structures are various springs and masses which comprise the real physical machine. Although it may not be intended that a given linkage have the properties of a parasitic spring or mass, this is nonetheless true of essentially every piece of the machine. Therefore, energy storage via spring distortion and the momentum of parts of the machine play a role in the results obtained. In order to remove effects caused by such factors, it is important each individual pull test be done slowly so that the principle frequencies are below those of the resonance frequencies of the pull test machine structure. It is feared that such care is not always taken, especially when performing a large number of tests, where an unconscious drifting toward a more rapid throughput may occur. If very rapid pulls are performed, the test forces may read either unusually high or unusually low, depending upon the physical location and frequencies of the resonant poles. If the application head (hook or tweezers) has an appreciable mass and is more rigidly connected to the test piece than to the source of the pull-force, then the peak reading will reach a higher value than appropriate before the application head has been accelerated so that it communicates force to the test piece. It is possible that, by means of other architectures with hidden resonances that the reverse would be true. The pull-test machine generally uses a dash-pot, or other mechanism, to regulate the speed at which force is applied. If adjustable, it should be set for the appropriate rate. However, often many choices of loading mass are available; the selection of an inappropriately high mass will cause too rapid an onset of force.

Two methods of attaching to the test piece leads were used; each had its advantages and disadvantages. The use of a hook to pluck the lead is simple and direct from an operational viewpoint, but requires special attention to ensure that it is always placed the same distance from the die, for reasons discussed above. There is also the matter of interferences to neighboring leads. When these small leads approach so closely, it is possible to pre-stress the subsequent lead by incidental contact while engaging or in pulling the current lead. Another matter is peculiar to the hook: A type of curved depression exists in the hook, into which the lead may fit in various postures. Although it is assumed the lead is free to settle into the position of least energy as the pull proceeds, friction or other forces may prevent this from occuring, and thus lead to an element of stray torque upon the lead. The effects of such a torque are best understood along with the discussion of the "jog" or "dog-leg" effect below, since it is under such conditions that the most significant torques are likely to develop. Using a hook also means that the other (not to be pulled) end of the lead must be constrained. Conversely, with the use of a tweezers type of mechanism, the other end of the lead must be free so that it is available to be apprehended by the tweezers. This requires

that a lead be severed by some mechanism prior to the pulling. Possible damage can occur, during this severance, which later might naively be attributed to the pull test alone. When a pull test results in a radically low value due to this effect, then any earlier result from a SLAM evaluation which gave a good bonding value to the lead is held in question. Moreover, in order for the tweezers to seize the lead, it must first be bent upward into a receivable posture. This act of bending the lead might cause incidental damage, which could also be naively attributed to the pull itself. However, if the severance and bending are done with some methods that allow no incidental damage, and if the tweezers then are applied in an even posture, clear of any area of "dog-leg" (see below), the vertical direction of pull can provide relief from the variability due to angle-of-attack differences, due to hook position, with respect to the die in the previous case of hook pull. This straight vertical direction is likely to cause a sharper radius of curvature in the lead, thereby causing more concentration of force, thus a somewhat lower yield strength on a systematic basis. Unfortunately, it was somawhat belatedly conveyed to us by GTE, whose pull tests were those using tweezers, that the method of severance included using a regular pair of scissors. This method, quite obviously, is apt to produce not only a strong amount of shear force at both ends of the lead (if the lead, not cleanly cut, is pulled longitudinally), but also produces a measure of lifting and twisting due to subtle difficulties in handling, and also an amount of shock as leads are released from tension when finally severed. A large number of sample pieces containing dozens of zero-value pull strengths due probably to this cause were found. Unfortunately, their SLAM test had been performed, and many bonds sites had been shown by SLAM to be of good coverage. Juxtaposed with the zero and near-zero value of their pull tests, they falsely appear to show that many bonds of extreme low strength escape detection by SLAM, even being rated by SLAM as being of very high bonding percentage. If not carefully noted, these exceptions virtually sabotage the test results in the cases of the parts so subjected. Fortunately, this effect clearly is limited to those samples subjected to that type of severance, and then being most pronounced among the particular samples whose initial bonding conditions may have predisposed them to be weaker and thus more susceptible to such procedural damage. It is to be most emphatically required that such methodology be avoided at all costs during any subsequent test regimen. Mistakes are only valuable if their lessons are well heeded.

THE EFFECT OF A "DOG-LEG" OR "JOG"

When graphed as abscissa and ordinate, the SLAM bond percent vs. "GRAMS" pull show a general tendency toward a monotonic and nearly linear relationship at lower bond percent values, and then shows a tendency toward saturation at the higher bond percents. This is a result of the fact that with higher bond percentages, the complete width of the bonding area tends to be filled; because of the "peel test" nature of the test, strength is limited by this width rather than by the entire bond area. However, the scatter is extreme in certain samples. Graphing only the pull test values as ordinate, with the position numbers of the leads as abscissa, however, shows a strong relationship. In graphing an individual piece, a smooth relation is not always seen. However, what IS seen is that values tend to be uniform (and near expected value) along the middles of edges of the die, and are erratic, and generally lower (often much lower) at positions corresponding to near the die corners. If the ILB samples are averaged together, and then graphed with pull test as ordinate and position as abscissa, the trend becomes EXTREMELY plain:

> Something happens near the corners of the samples which either
> 1) truly weakens the bonds formed; or
> 2) causes them to be READ as weak by a pull test.

This unknown factor is a smoothly varying factor; it effects not only those leads immediately in the vicinity of the corners, but also seems to affect all leads in an amount decreasing in a nearly sinusoidal manner, as the middle range of the edge is approached. Also, this factor appears absent or much reduced in the outer lead tests, and absent, or much reduced and of a different character, in the MESA ILB samples. Furthermore, nothing like this effect is seen in the SLAM results, or the optical microscopic evaluations performed so far. In short, it seems to be directly traceable to situations which include hook-mitigated pull tests on solder inner lead bond samples, with increasing prominence nearest die corners.

The original mind-set of these experiments was that the pull-test was a virtual absolute; an unimpeachable standard of the integrity of bonds, against which any other method could be measured. It is true that some other method was needed, because after all, testing by the pull test was destructive; much like testing the integrity of kitchen matches by striking them.

So far, the description of inherent potential flaws in pull tests has been confined to elements of the methodology. It is easy to agree that certain measures of care should be taken during testing to ensure that sloppy results do not appear. However, none of the cautions has anything to do with the test sample itself. All such sites on the sample are believed to be fungible. That is to say, although the bond which occurs at a given site may test as weak or strong, the fact of it being at that given site is unimportant; no significance is attached to that position with respect to the act of the pull test.

Now this trust in the fungibility of the leads appears threatened. Because of the definite periodic nature of the deviation from the expected pull test values, it must be decided whether the strength of the bonds actually vary, with respect to their position around the die, or whether the servicibility of the pull test itself is subject to variation with respect to position.

There is a way to preserve the ostensible insensitivity of a pull test to positions, but only by transferring the mechanism of the observed deviations to elements peculiar to the sample, and which are peculiar in ways which directly affect how the sample changes a parameter within the pull test methodology. First, however, it would be prudent to examine whether it is necessary to make this allowance; that is, whether the bonds at the corners might not be indeed weaker than those in the middle of the die.

As one line of evidence, it can be clearly shown from the data of the SLAM bond percentage tests, that SLAM is not influenced by any such corner effect. When normalized averages of SLAM data are put against positions, a smooth and nearly level curve indicates that little if any effect of position is observed. However, it is SLAM data itself which is being scrutinized, and it is no more prudent to let SLAM be its own judge than to have let the pull test do the same for itself. A certain benefit arises from the fact that the tests are destructive; a body of residual evidence exists, which can be subjected to further study.

When optical micrographs of the corpi delectorum are reviewed, it can be seen rather clearly which bonds indeed had possessed a good integrity, and had to be violently parted. These bonds show rough granularity and the obvious signs of having been torn apart by the application of force to an originally nearly homogenous structure. Those bonds which registered only weak bonding, by both SLAM and the pull test, show a smoother imprint, implying that the surfaces had been merely pressed into conformity, and did not attain a good bond in the original bonding process. However, those bonds at the corners, or near the corners, which gave modest to good SLAM bond, and yet which showed poorer pull test performance, are optically very similar to other bonds which the pull test ranked as good.

The optical micrographs anticipate that the pull tests should have been fairly high, and agree with the SLAM evaluations. There thus seems to be strong correlation between the optical views, and the SLAM evaluation. Both also agree well with the pull test results from the middle positions of the samples; but near the corners, it appears that the pull test results depart much of the time from results obtained by the other two methods, and become erratic, and generally lower in value.

Although it may seem repugnant to question a generally trusted and well-used methodolgy such as the pull test, it is perhaps totally disingenuous to disregard plain and direct optical evidence. Thus it seems that an adjustment must be made. The only thing which is so far lacking is a conceivable mechanism with which the disparity can be explained.

In looking for the mechanism, certain clues seem notable. One is the distinctly sinusoidal nature of the disparity, which suggests that the source

may be an angular phenomenon. The most apparent place where an angle comes into play is at the "dog-leg" or "jog" in the beam lead as it transits from the OLB site to the ILB site. Accordingly, a graphical comparison was made between the angles at these places, and the average values of the disparity. Assumed is that the pull test values would be a constant, without regard to die position, all other parameters being held constant. Since the pull test values come from many different pedigrees of sample with respect to time, pressure, and temperature, for this purpose they have been normalized against their highest in-sample value (set at 1.000). The values for each position number are averaged, and are further averaged down to only eight positions, reflecting the fact of the near symmetry of the samples; a position can only be at a relative position to its nearest corner by a rank of 1,2,3,..to 8. Since the averaging causes the values to reflect the mean value of the highest and lowest normalized values, the expected values with all other conditions held constant might tend (arbitrarily), to be 0.707 at each position regardless of their sample position number. To reflect this, the eight values so obtained are renormalized, so as to be expressed as the fraction of 0.707 that they represent.

Corner-relative Position #		Averages by pos, folded into 8 places	Averages Normalized By y/0.707		
Actual sample position numbers. #10 is vacant				θ at pos 64-57	$\cos(\theta)$
1,16,17,32,33,48,49,64	1	0.38663	0.54678	57°	0.54464
2,15,18,31,34,47,50,63	2	0.46524	0.65795	55°	0.57358
3,14,19,30,35,46,51,62	3	0.49045	0.69360	53°	0.60182
4,13,20,29,36,45,52,61	4	0.52354	0.74040	51°	0.62932
5,12,21,28,37,44,53,60	5	0.56684	0.80163	48°	0.66913
6,11,22,27,38,43,54,59	6	0.60467	0.85513	43°	0.73135
7, *,23,26,39,42,55,58	7	0.67685	0.95721	35°	0.81915
8, 9,24,25,40,41,56,57	8	0.69935	0.98902	23°	0.92050

* -(vacant position 10 taken as the average of 9 and 11)

To express the angles of the leads, the set of leads from 57 to 64 are taken as representative. Exact angles are not known, but are estimated by careful measurement of a mechanical diagram of the 64 position sample piece. The cosines of these angles are found, and listed in the last column. A strong agreement is seen between this column, and the column containing the averages normalized by 0.707, causing a great suspicion that the "corner effect" actually is related to the angle of these "dog-legs" or "jogs" in the lead.

Should this be the case, it would give further support to the idea that the pull test itself is suspect, rather than that the sample really does become weaker near the edges AND that both optical and SLAM evaluation somehow themselves fail near the edges. The cause of this support is twofold:

1) There is not known any specific reason why the angle of the leads should affect the gang-bonding, since the leads are confined to the plane of the die face during bonding, and the angle can apparently have no effect.
2) During the pull test, the hook most certainly does cause the lead to emerge from the plane of the die, and in so doing, can interact with these angles by generating a torque upon the lead, thereby influencing the geometry of the pull.

Upon reflection, it is seen that if a hook is used to pull a lead which has a dog-leg, the lead will tend to curl. This causes more concentration of force at the zone where the tightest curl meets the bonded area. The degree to which curling will occur depends upon where on the lead the hook is placed, how much angle exists, and how the lead is cradled within the curved valley of the hook. Each of these factors is a nearly random variable, since none are specifically controlled in the general pull test. However, at any combination of these variables, an amount of curling occurs and is an important factor in the apparent yield strength of the bond.

Reaction of a dog-legged lead is not limited to a hook, however. A tweezer type of puller may also cause a torque to be generated, if the tweezer grabs the lead at some distance from the bond, at a position which contains an angled portion of the lead between the bond and holding point. In the case of a tweezer, it becomes less possible to determine the chirality of the torque at the point of the bond, however, as the lead may buckle to either direction, and is not predisposed to one direction by the geometry of the pull at least until the buckling motion is further constrained by one or another geometrical factor. Therefore, the lead may tend to curl in an underward or overward sense with respect to the bond, since, unlike the case of the hook pull, there is little bias predicating an overward twist An overward twist tends more to concentrate at a smaller area the force, and thus cause rupture at lesser amounts of applied force.

This effect is just a specific case of the general mechanism of force concentration that is discussed earlier, wherein the local force is increased to a level sufficient to cause the rupture of the bond, although overall force, read externally at the pull test machine, is smaller than otherwise needed. A similar phenomenon allows a person of normal strength, but rehearsed in the technique, to accomplish the "parlor trick" of ripping apart a thick phone directory. It also routinely used by someone attempting to open a cellophane package.

The existence of this curling effect causes the more acutely dog-legged leads near the corners of the sample to yield at forces which are less than the forces measured at the middle of the sample. The variability seen is the result of the many uncontrolled factors which are present in the production, in each instance, of the effect.

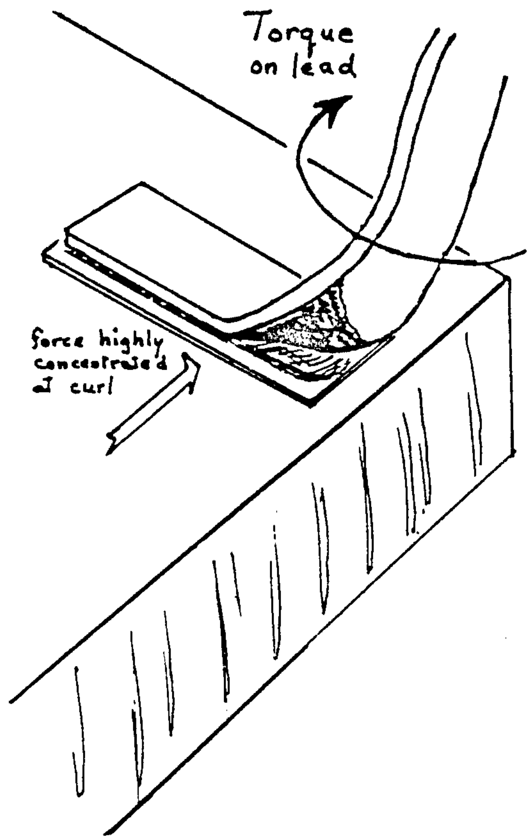


Figure B.1.3 Effect of Torque on Lead

OTHER PERIODIC EFFECTS

The identification of a "corner effect", due to systematic error in the pull test conditions does not preclude that other periodic effects might actually be inherent in the sample itself, and not in the pull test. However, if other periodic effects are actually inherent in the sample, they should be detected by any applicable method, and not mysteriously appear only in the data from one type of test. Such an effect is indeed seen in ILB solder TAB samples. When the corner effect is reduced, in the plot of pull-test versus position, by the method of nulling it out through averaging with neighbors, a single-period (one period per pass around the sample die) quasi-sinusoidal deviation is seen in the graph. Strikingly, a similar quasi-sinusoidal deviation of essentially identical magnitude and phase is seen in the SLAM bond% plot. The appearance of the pattern in both data sets virtually eliminates the possibility that it is due to systematic error in the tests. The alternative is that some property of the sample, or the way in which it was made, is actually prone to this modest variation with reference to sample position.

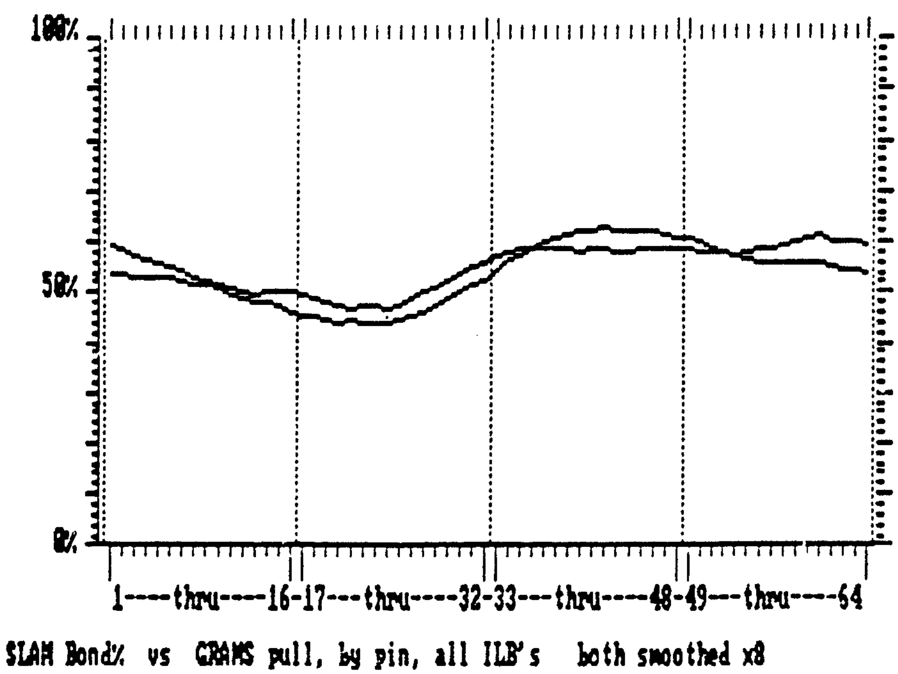


Figure B.1.4 Possible Process Non-Uniformity

Contents: Appendix "B" Section 2

Graphs pertinent to Periodic Effects
for ILB solder TAB samples.

—Covering all ILB's (pulled by Sonoscan or GTE)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

—Covering SS ILB's (pulled by Sonoscan only)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

—Covering GTE ILB's (pulled by GTE only)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

—Showing slower (tilt-related?) effect in ILB's
- -GRAMS pull, smoothed x0, x2, x8
  establishing the arithmetic removal of
  corner effect
- -GRAMS pull vs. SLAM Bond%; smoothed x8
  revealing corroboration of possible tilt

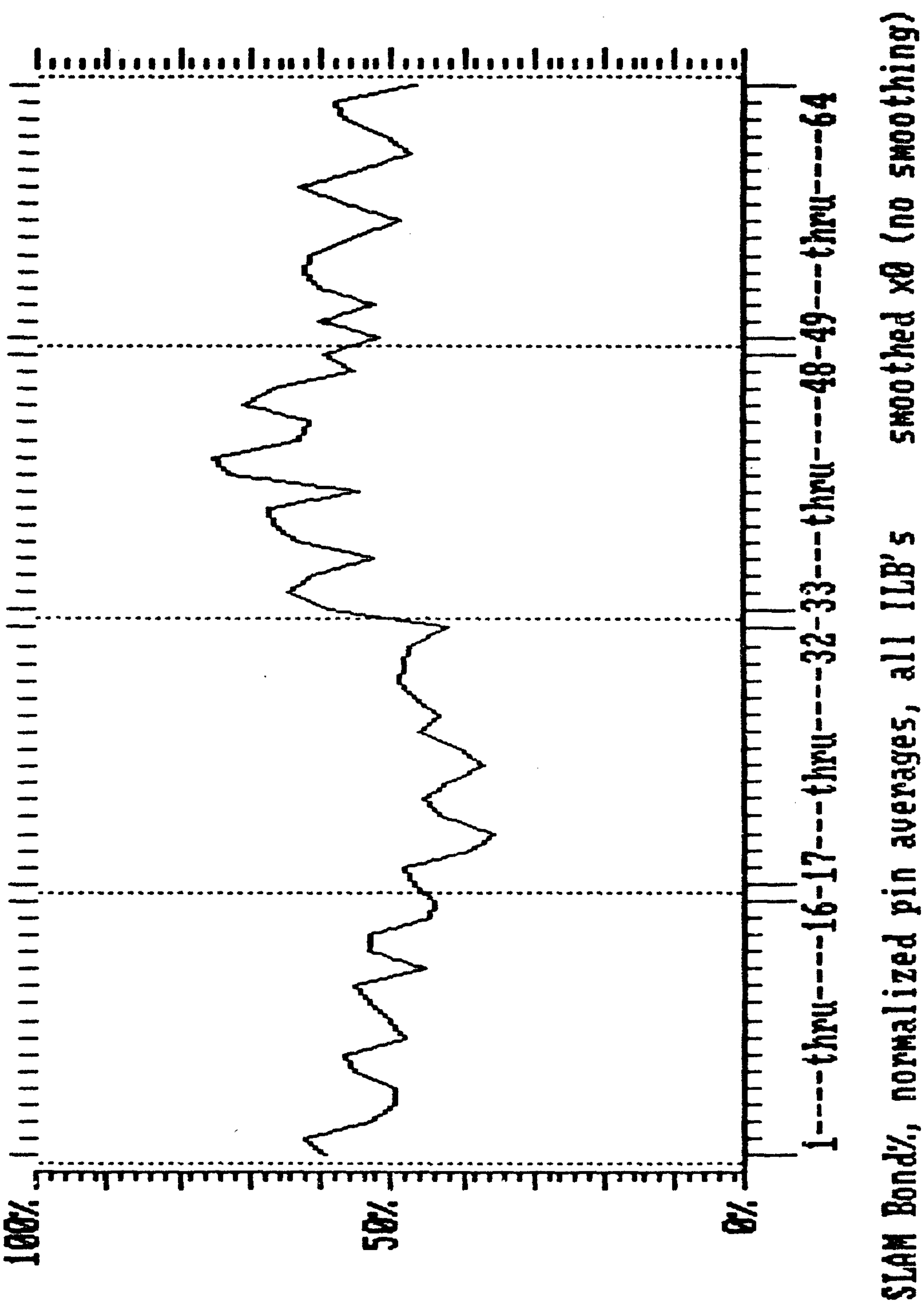


Figure B.2.1 SLAM Bond%, normalized pin averages, all ILBs smoothed x0

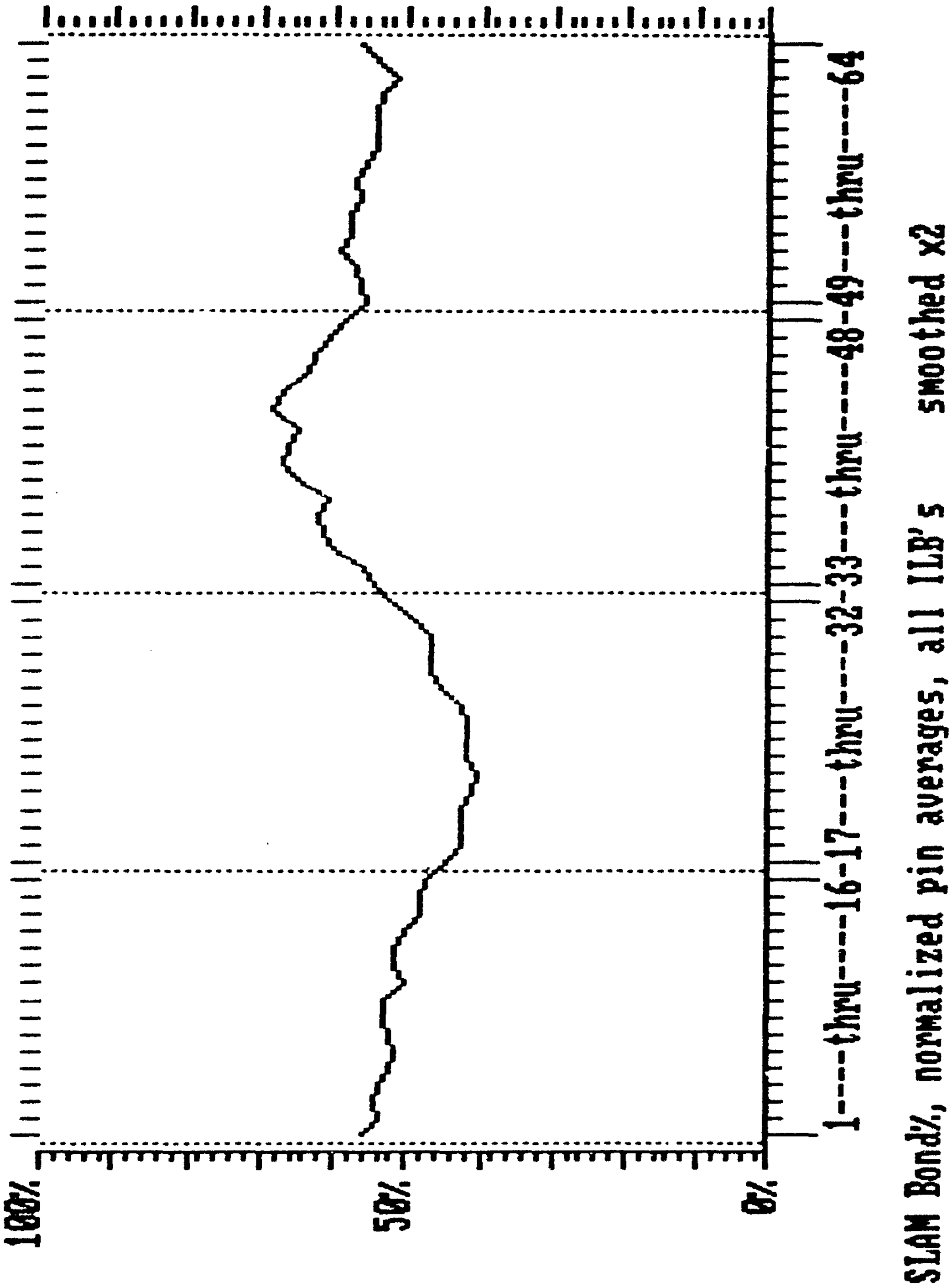


Figure B.2.2 SLAM Bond%, normalized pin averages, all ILBs smoothed x2

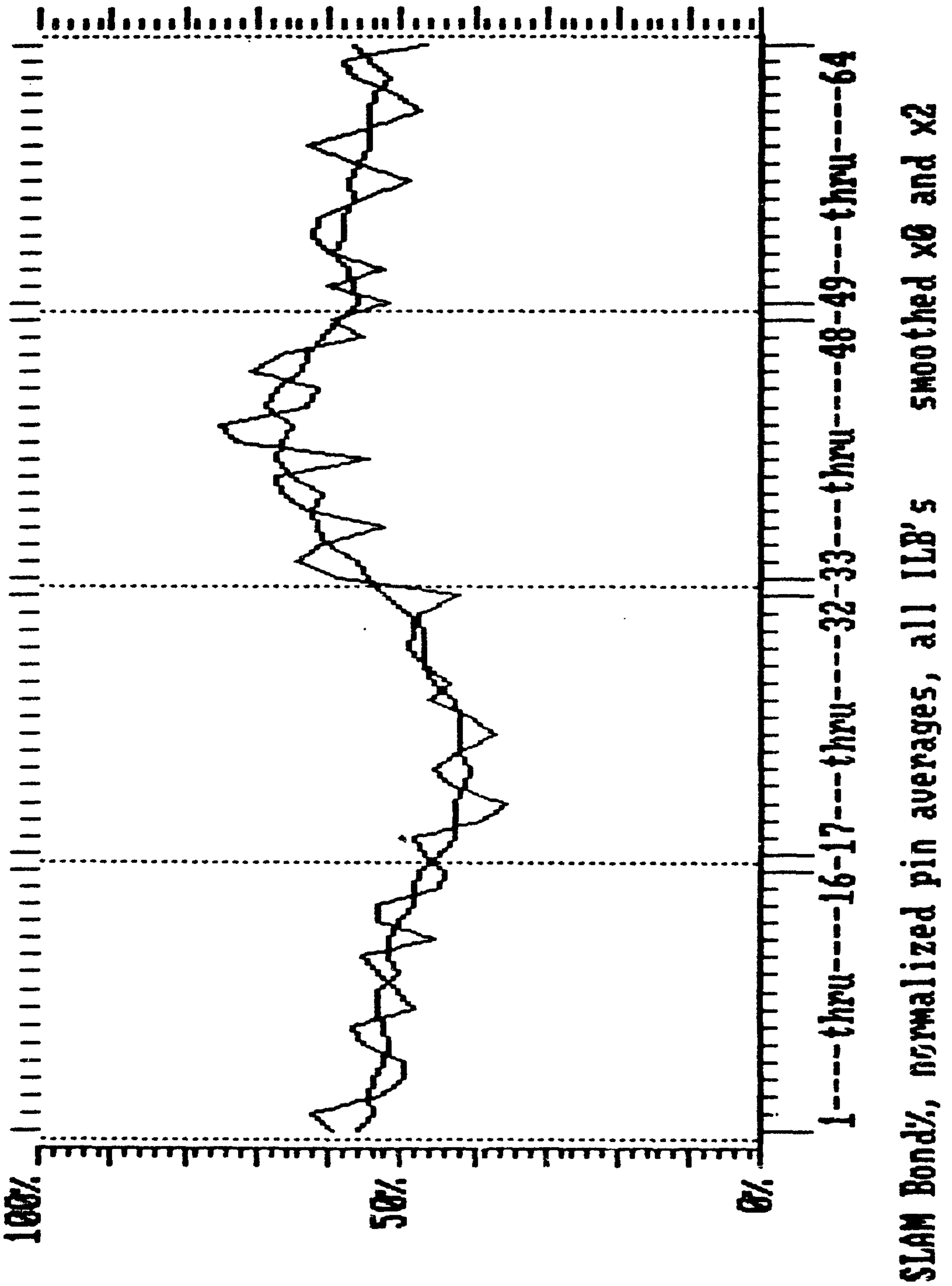


Figure B.2.3 SLAM Bond%, normalized pin averages, all ILBs smoothed x0,x2

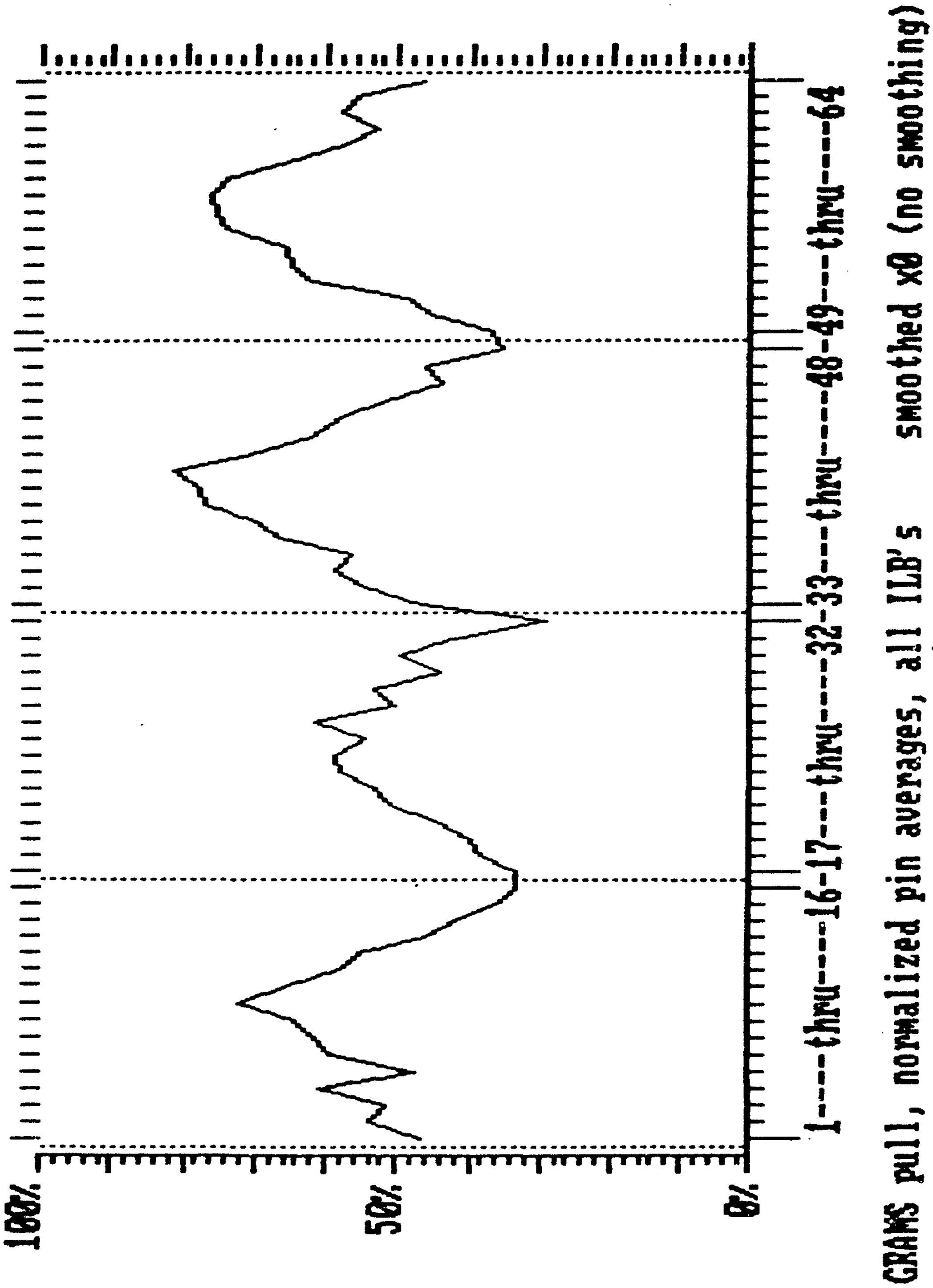


Figure B.2.4 Grams pull, normalized pin averages, all ILBs smoothed x0

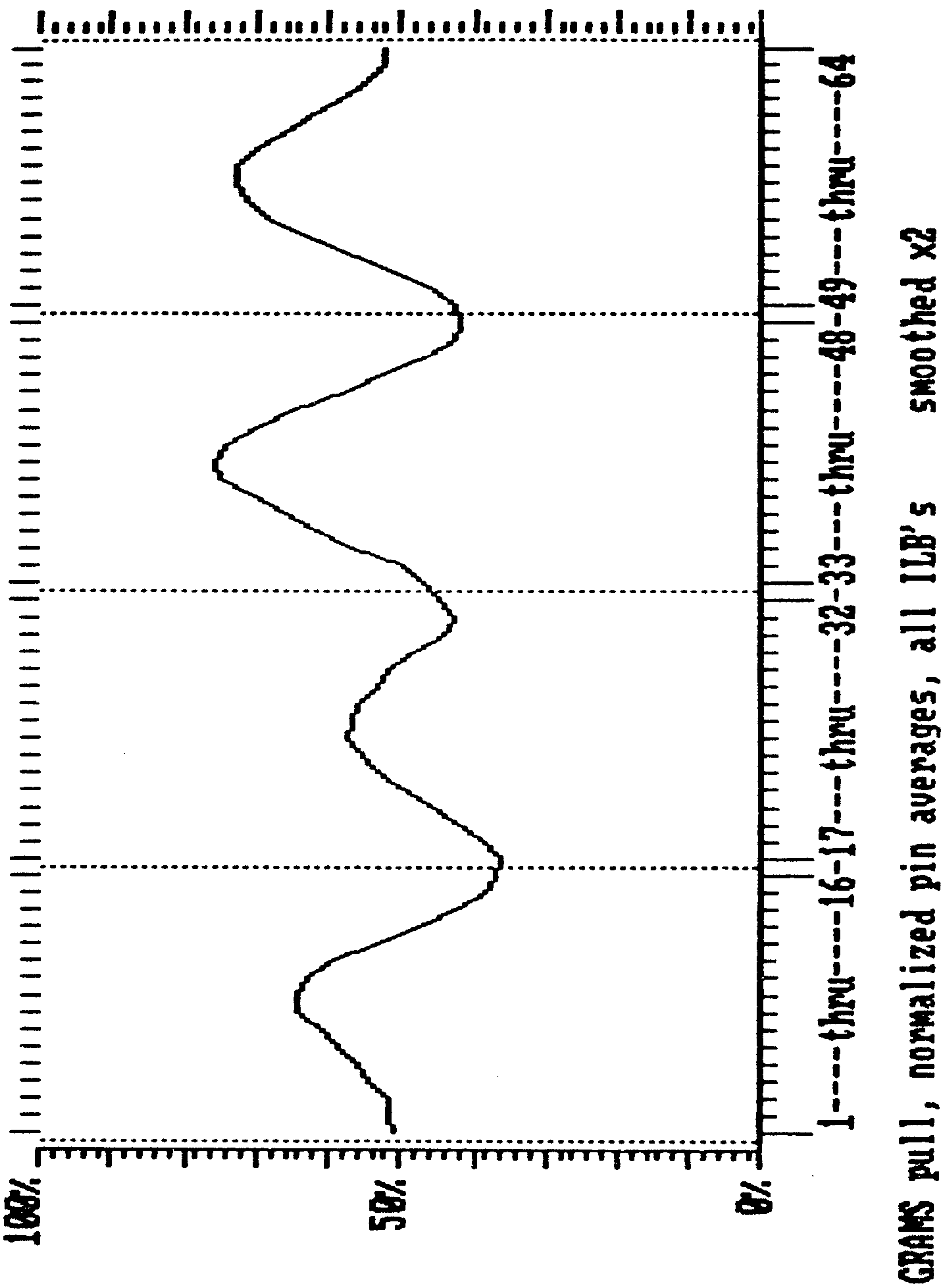


Figure B.2.5 Grams pull, normalized pin averages, all ILBs smoothed x2

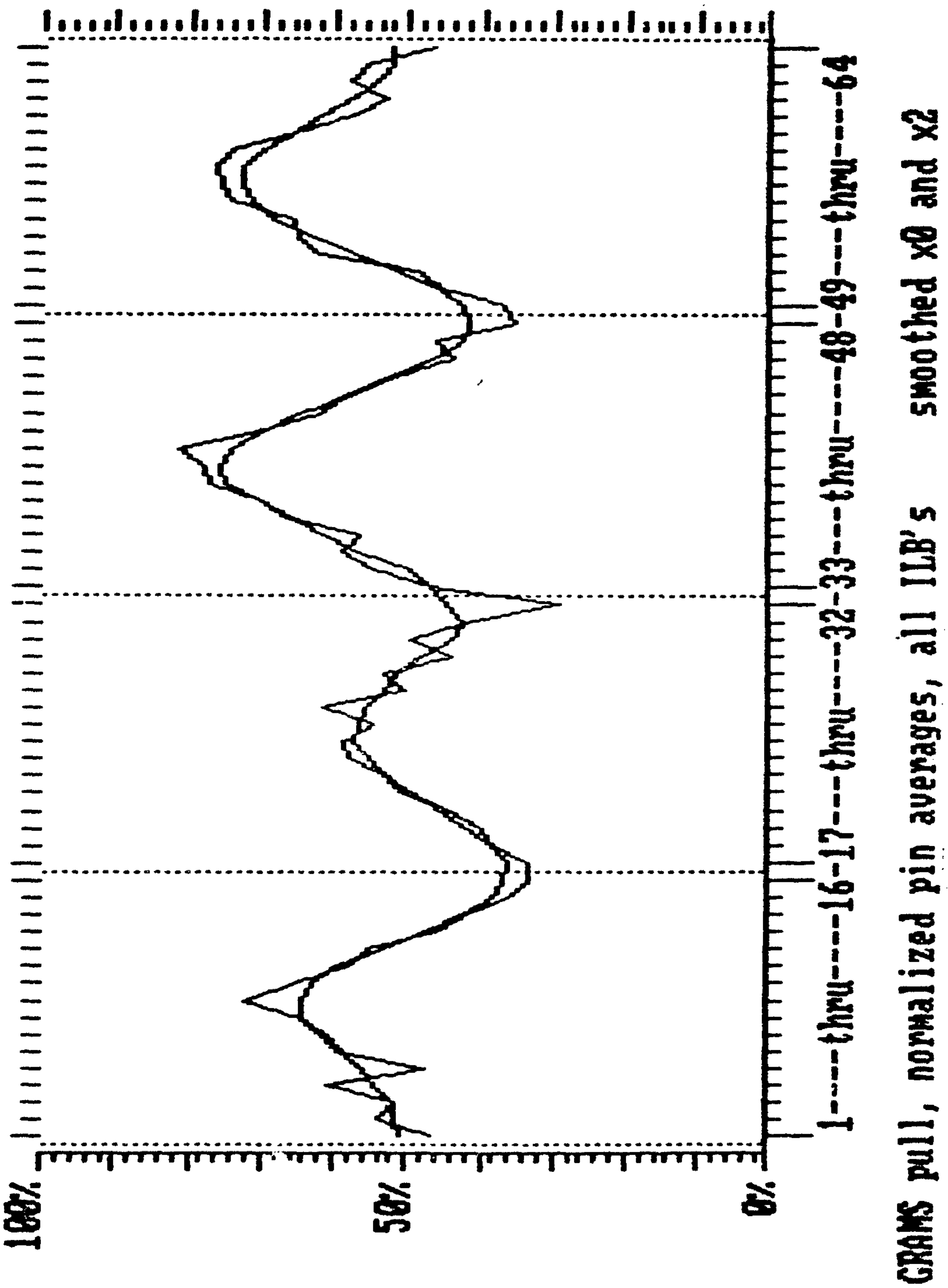


Figure B.2.6 Grams pull, normalized pin averages, all ILBs smoothed x0,x2

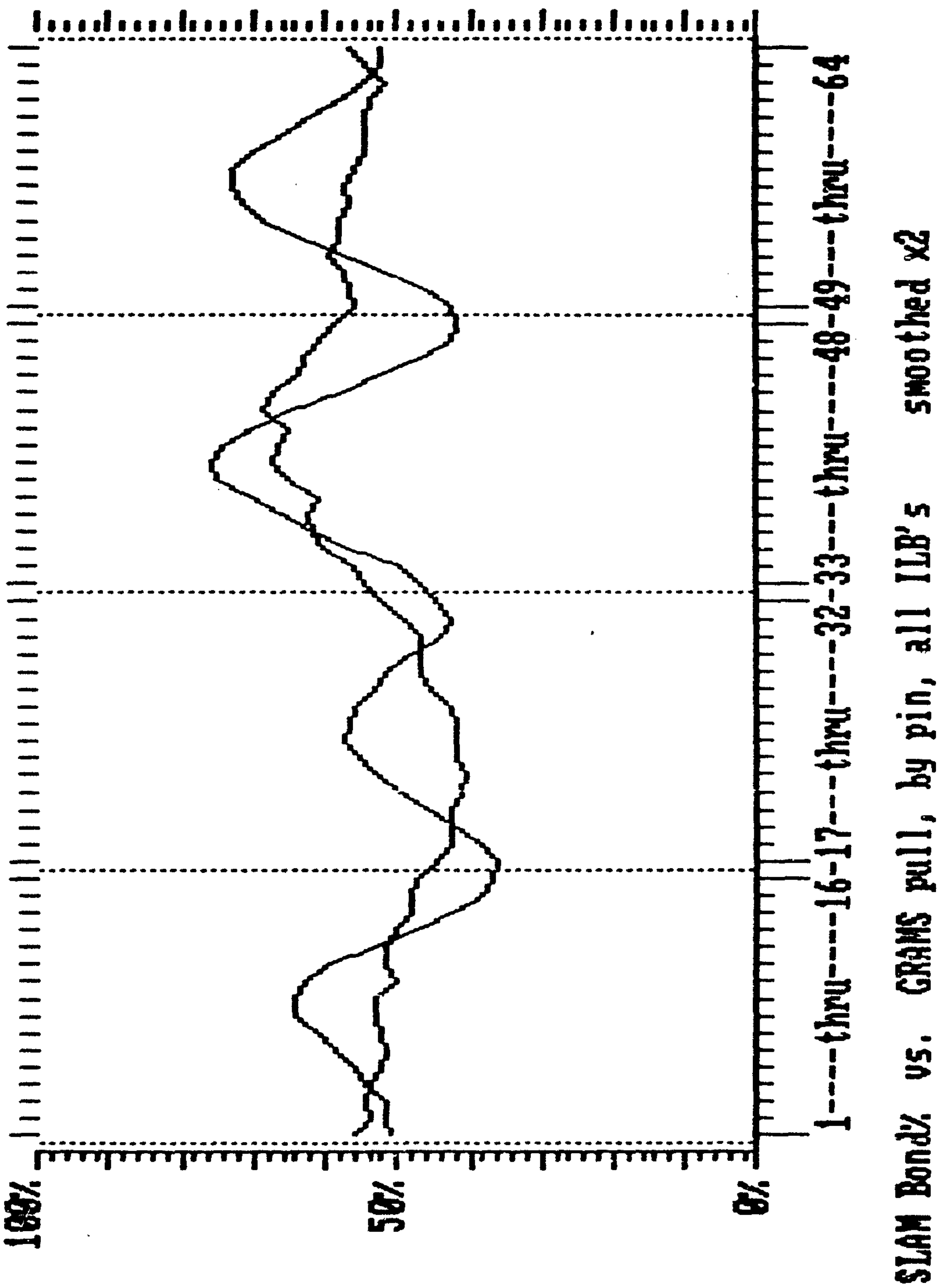


Figure B.2.7 SLAM Bond% vs Grams pull, by pin, all ILBs smoothed x2

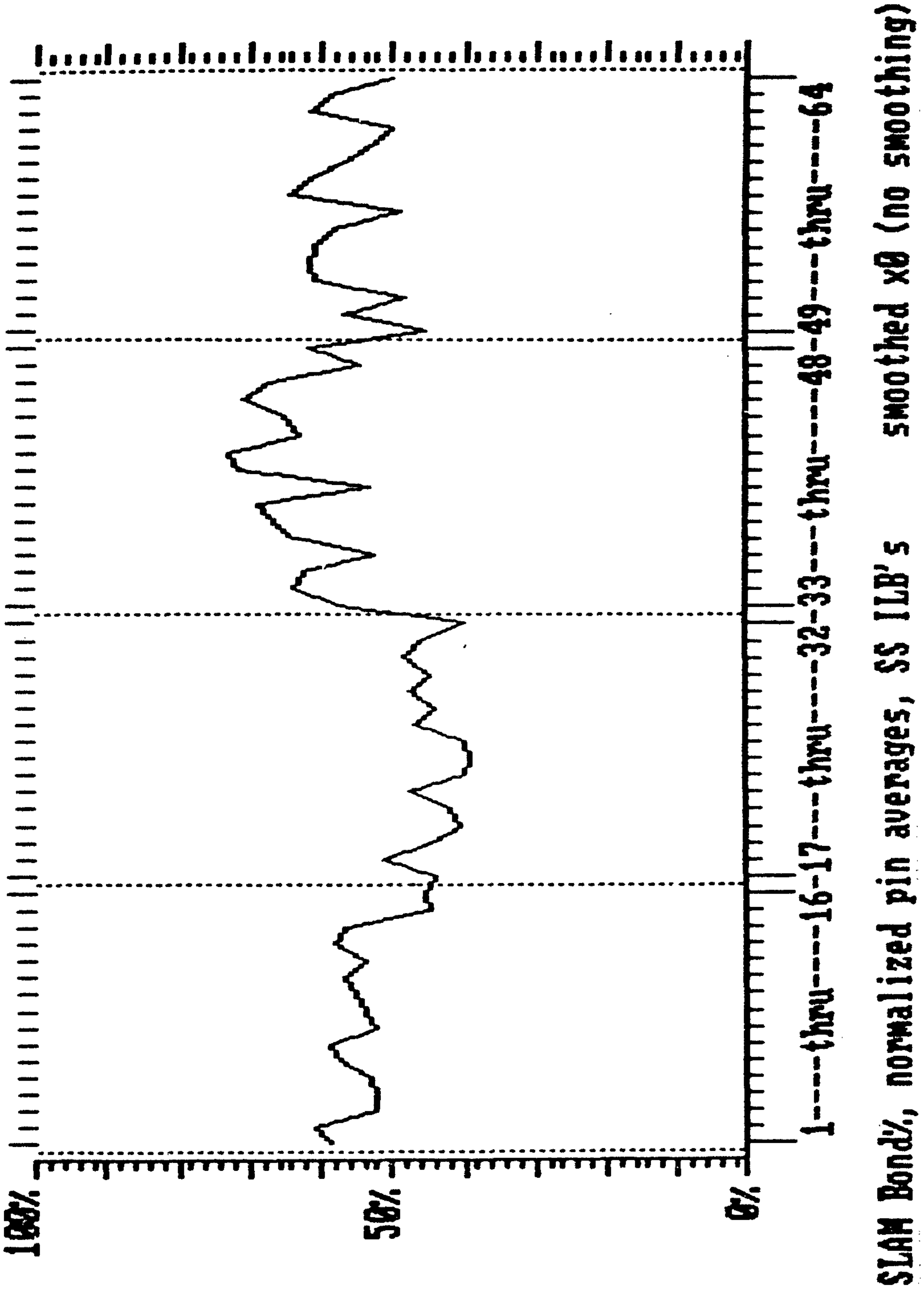


Figure B.2.8 SLAM Bond%, normalized pin averages, SS ILBs smoothed x0

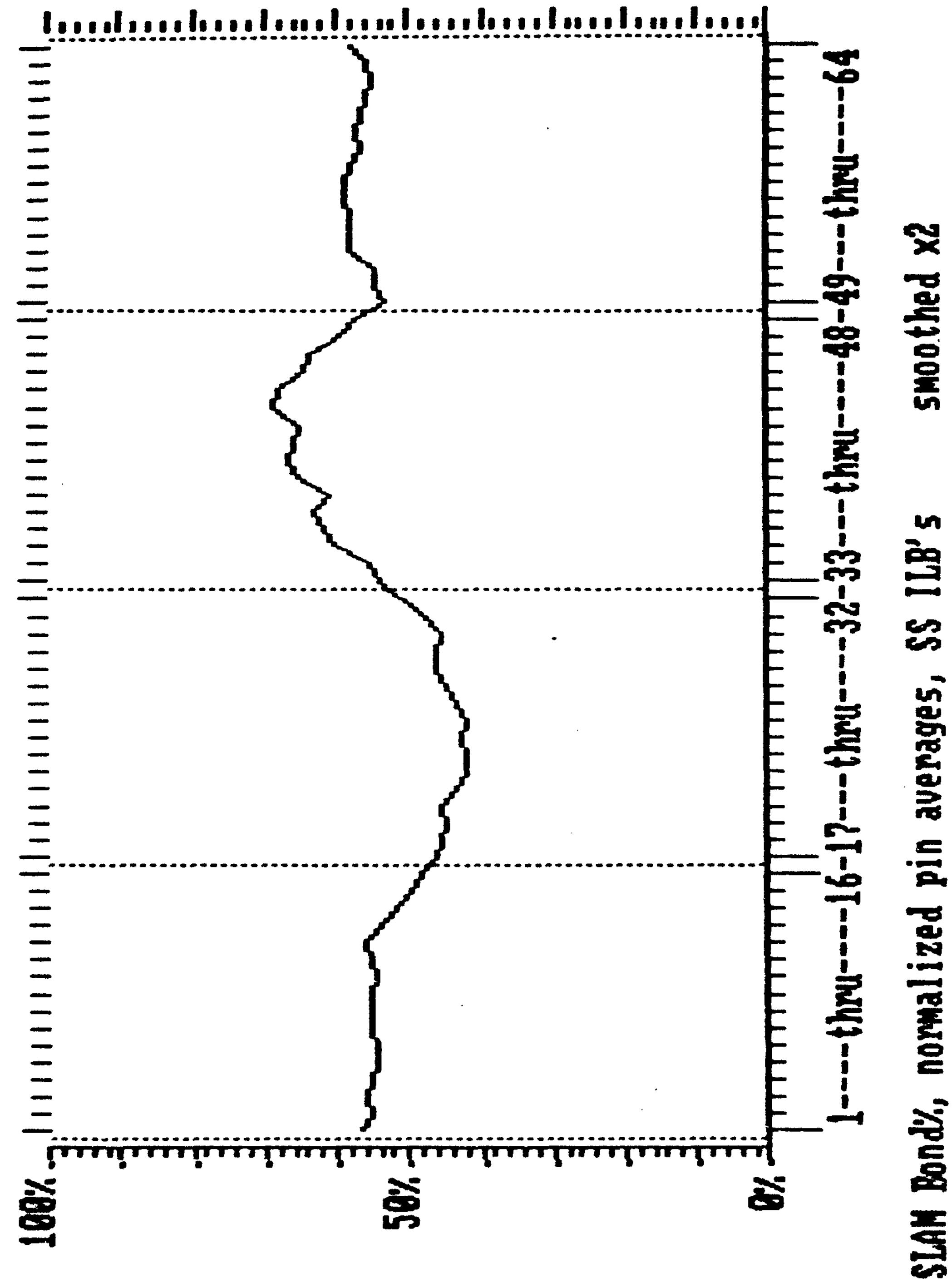


Figure B.2.9 SLAM Bond%, normalized pin averages, SS ILBs smoothed x2

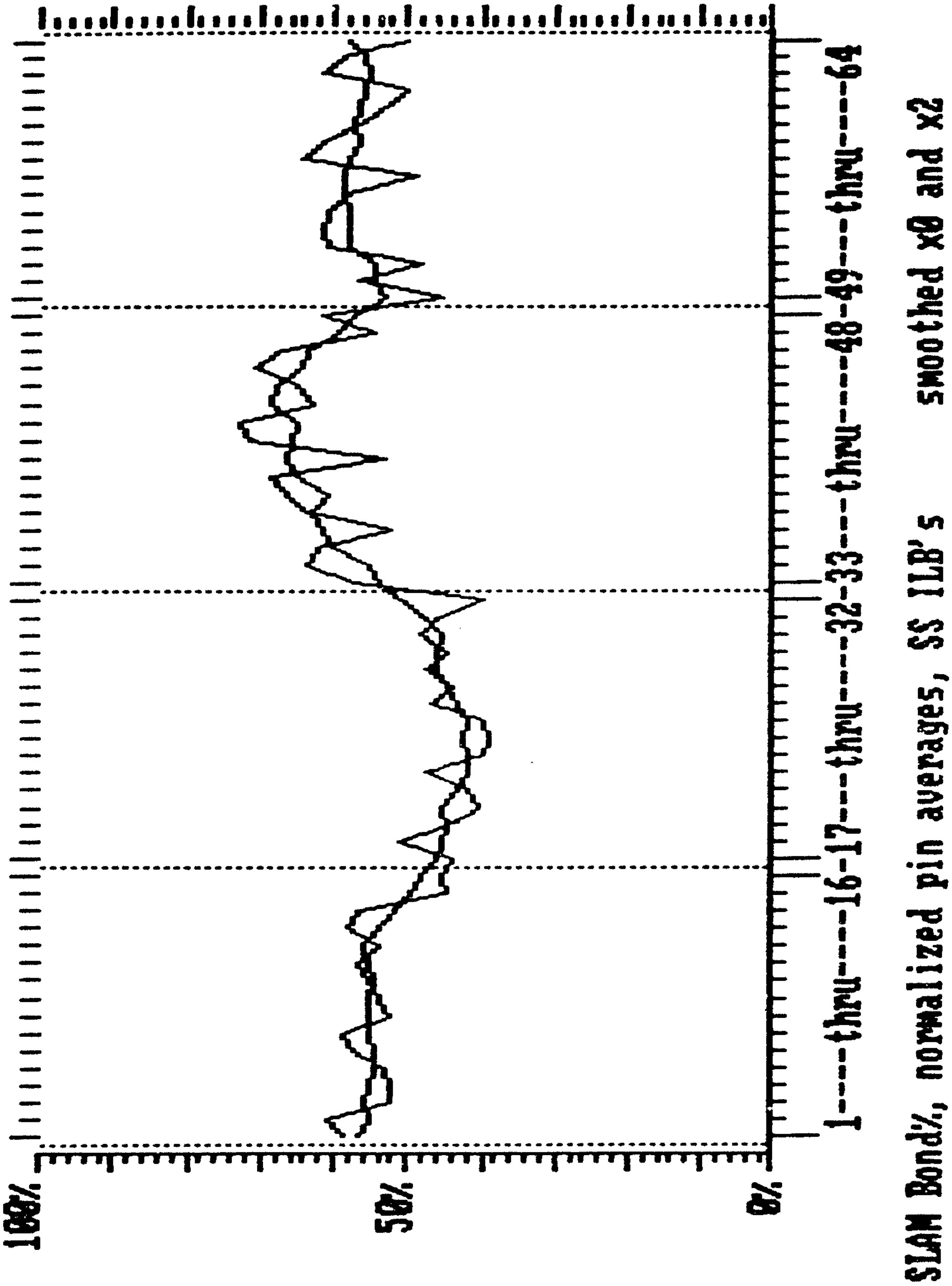


Figure B.2.10 SLAM Bond%, normalized pin averages, SS ILBs smoothed x0,x2

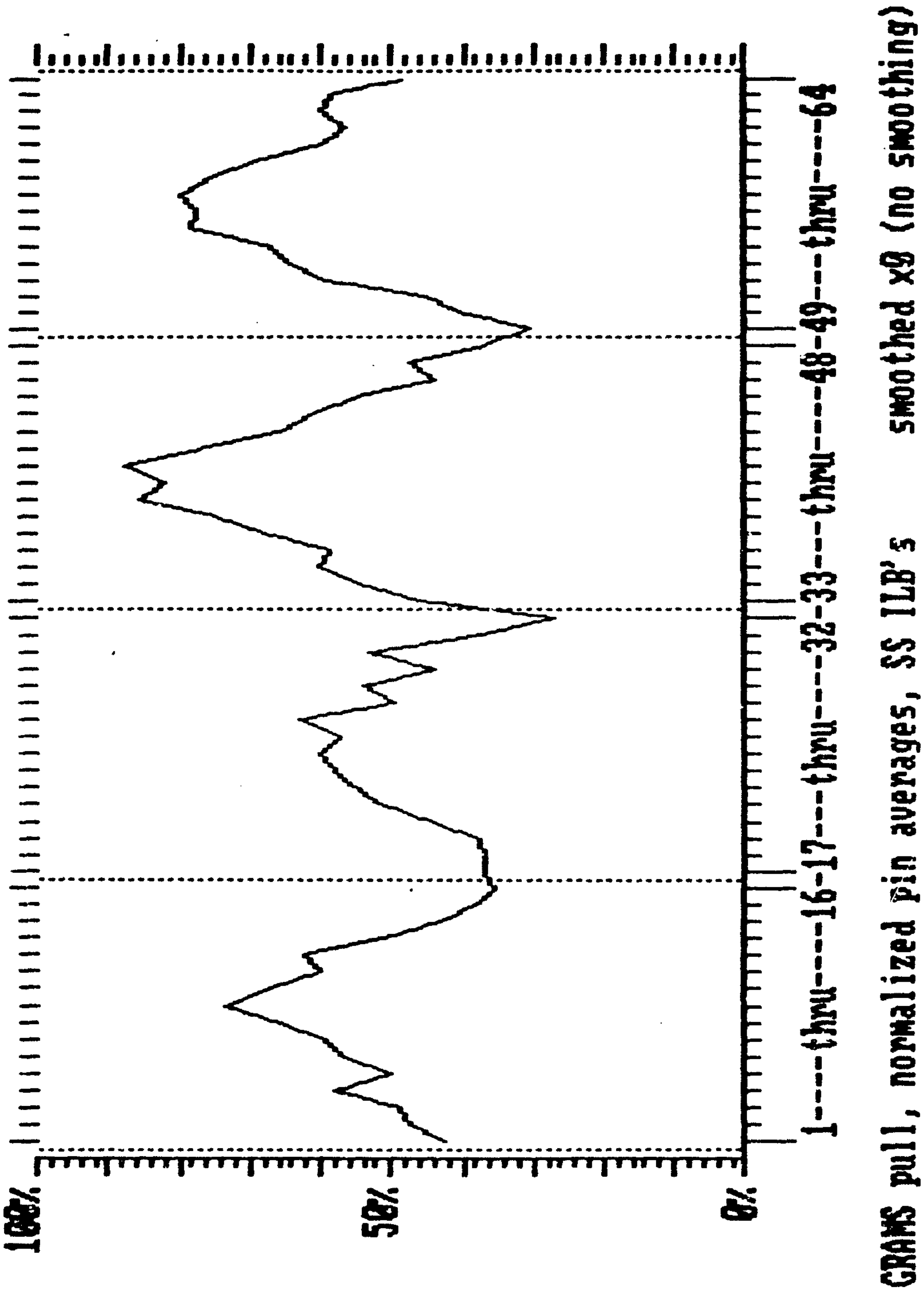


Figure B.2.11 Grams pull, normalized pin averages, SS ILBs smoothed x0

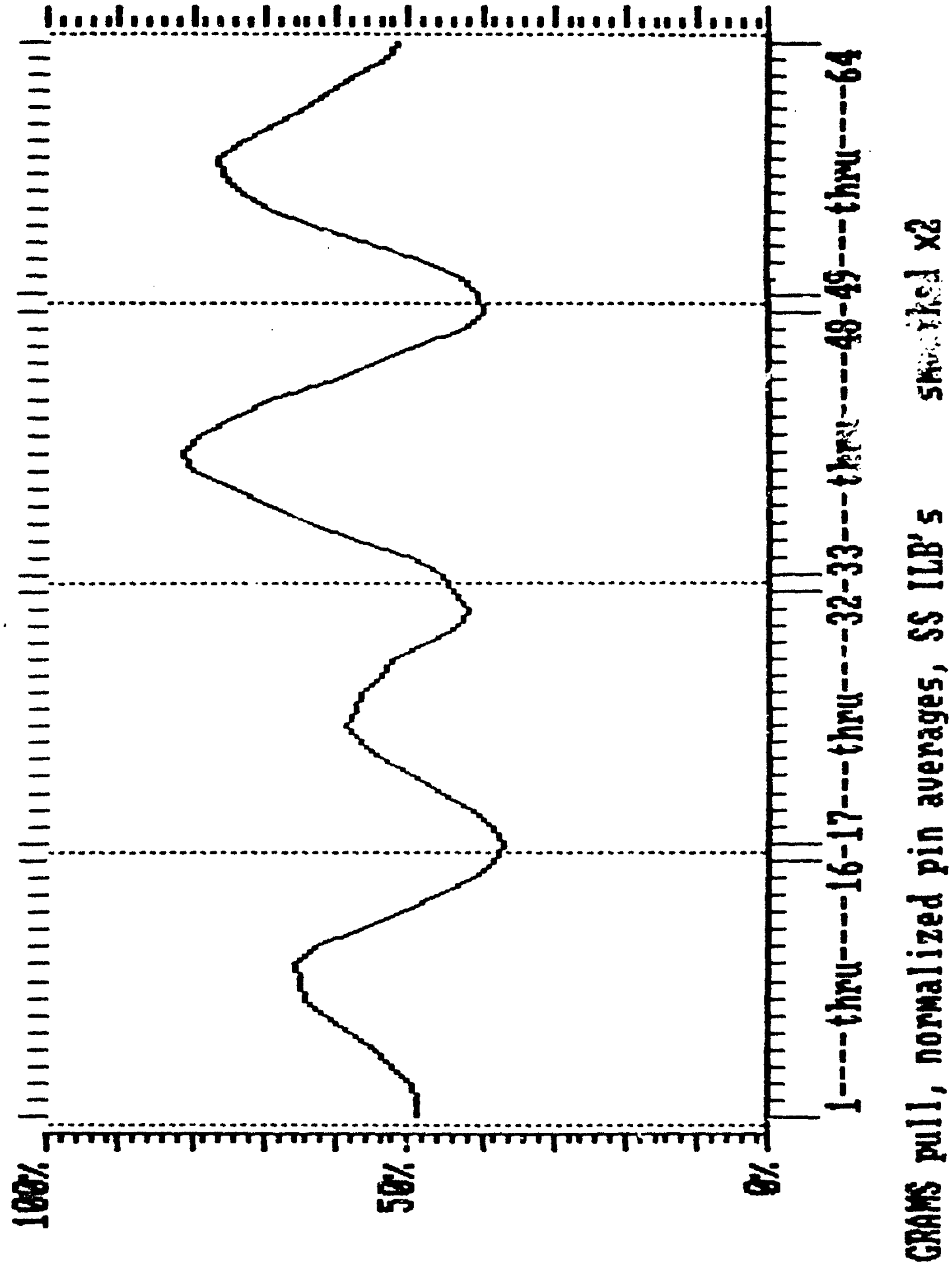


Figure B.2.12 Grams pull, normalized pin averages, SS ILBs smoothed x2

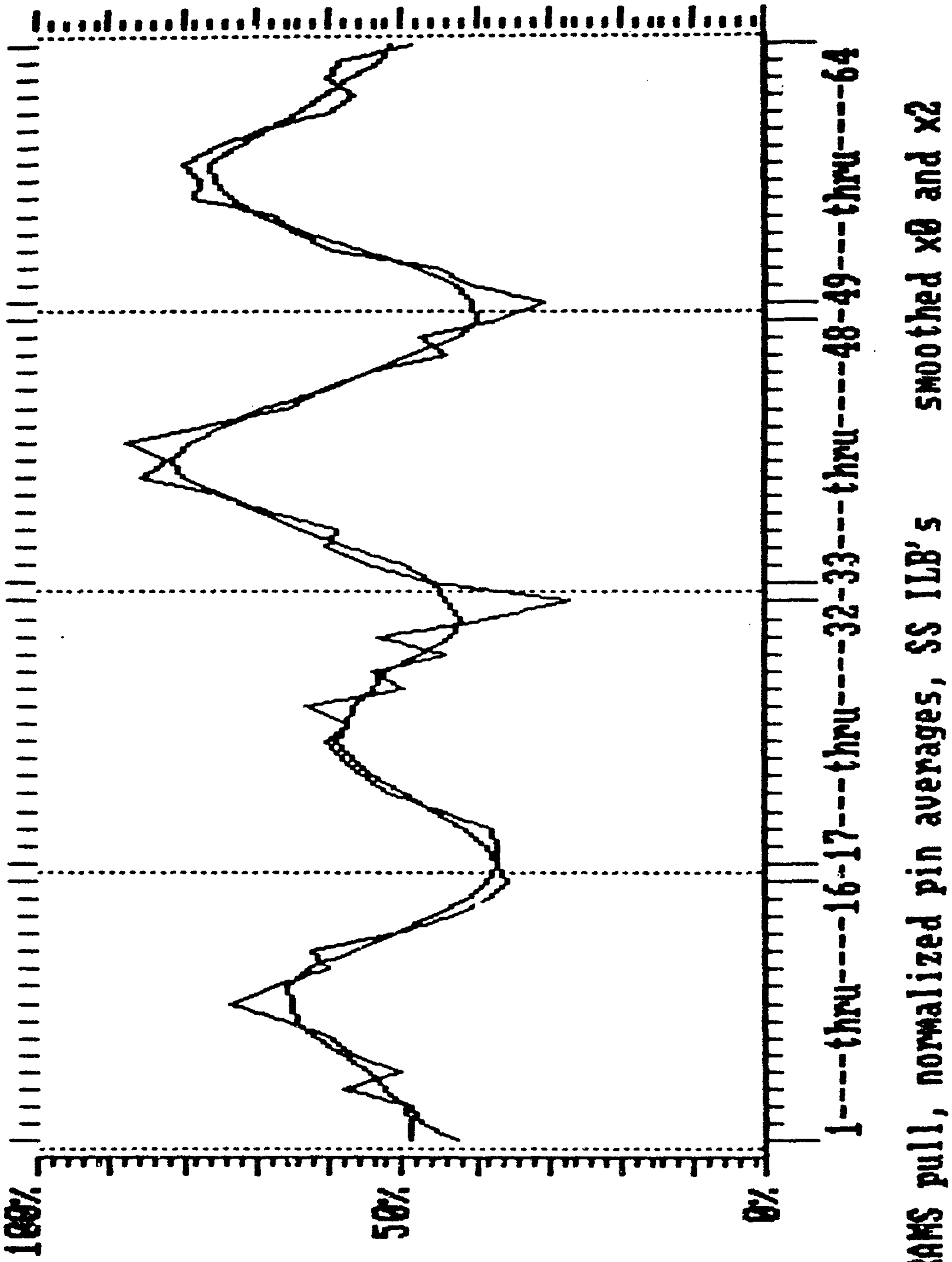


Figure B.2.13 Grams pull, normalized pin averages, SS ILBs smoothed x0,x2

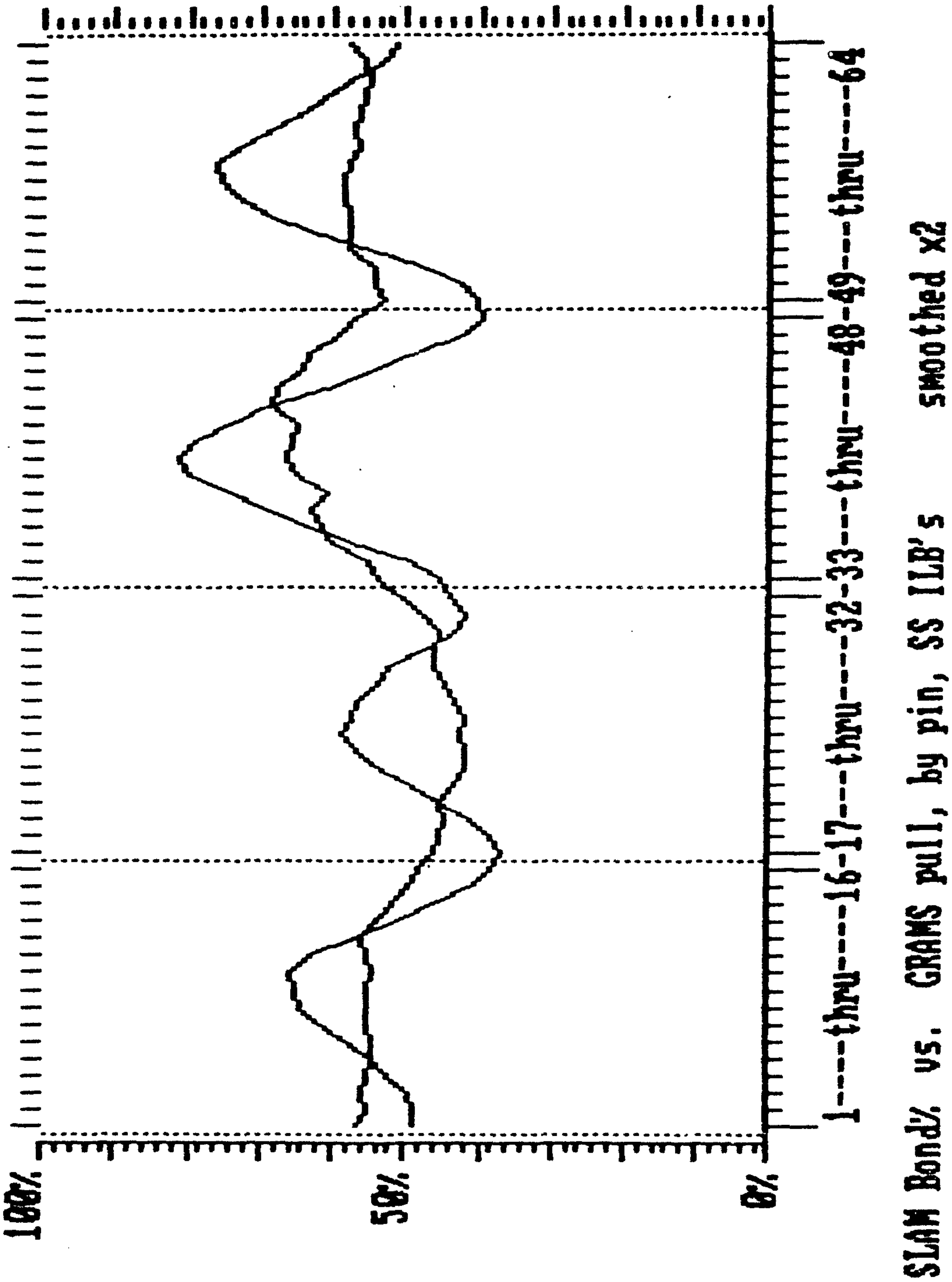


Figure B.2.14 SLAM Bond% vs Grams pull, by pin, SS ILBs smoothed x2

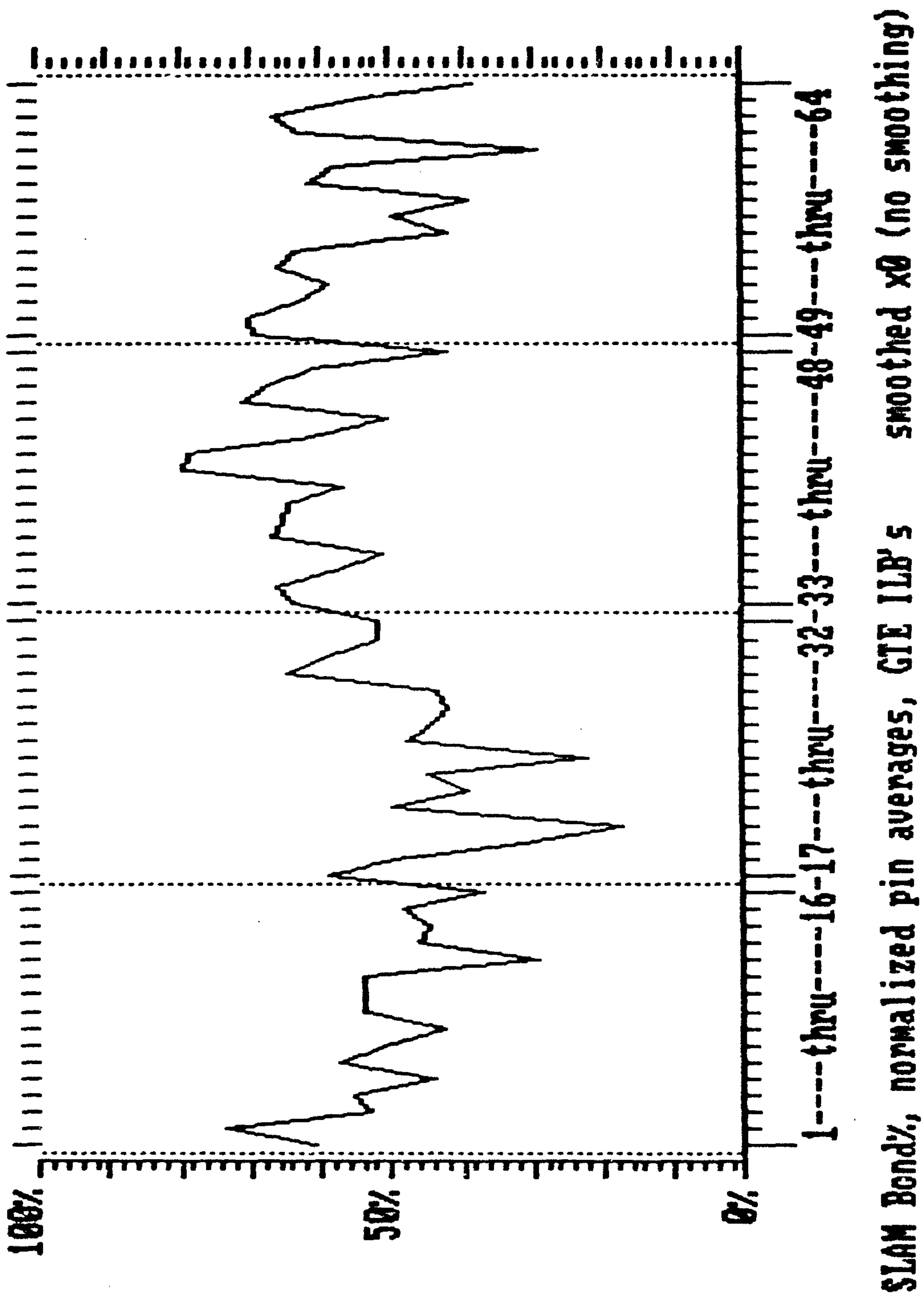


Figure B.2.15 SLAM Bond$, normalized pin averages, GTE ILBs smoothed x0

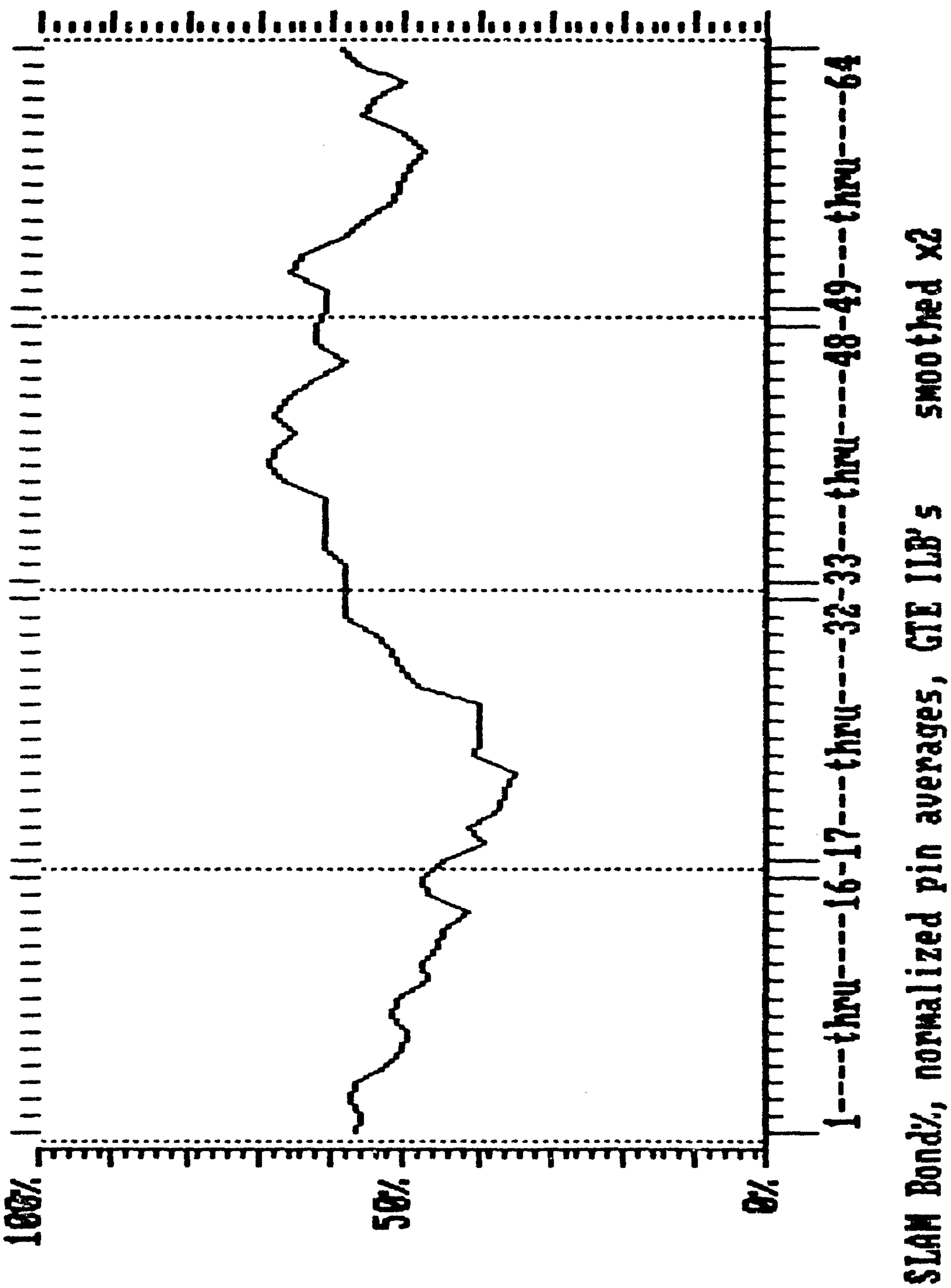


Figure B.2.16 SLAM Bond%, normalized pin averages, GTE ILBs smoothed x2

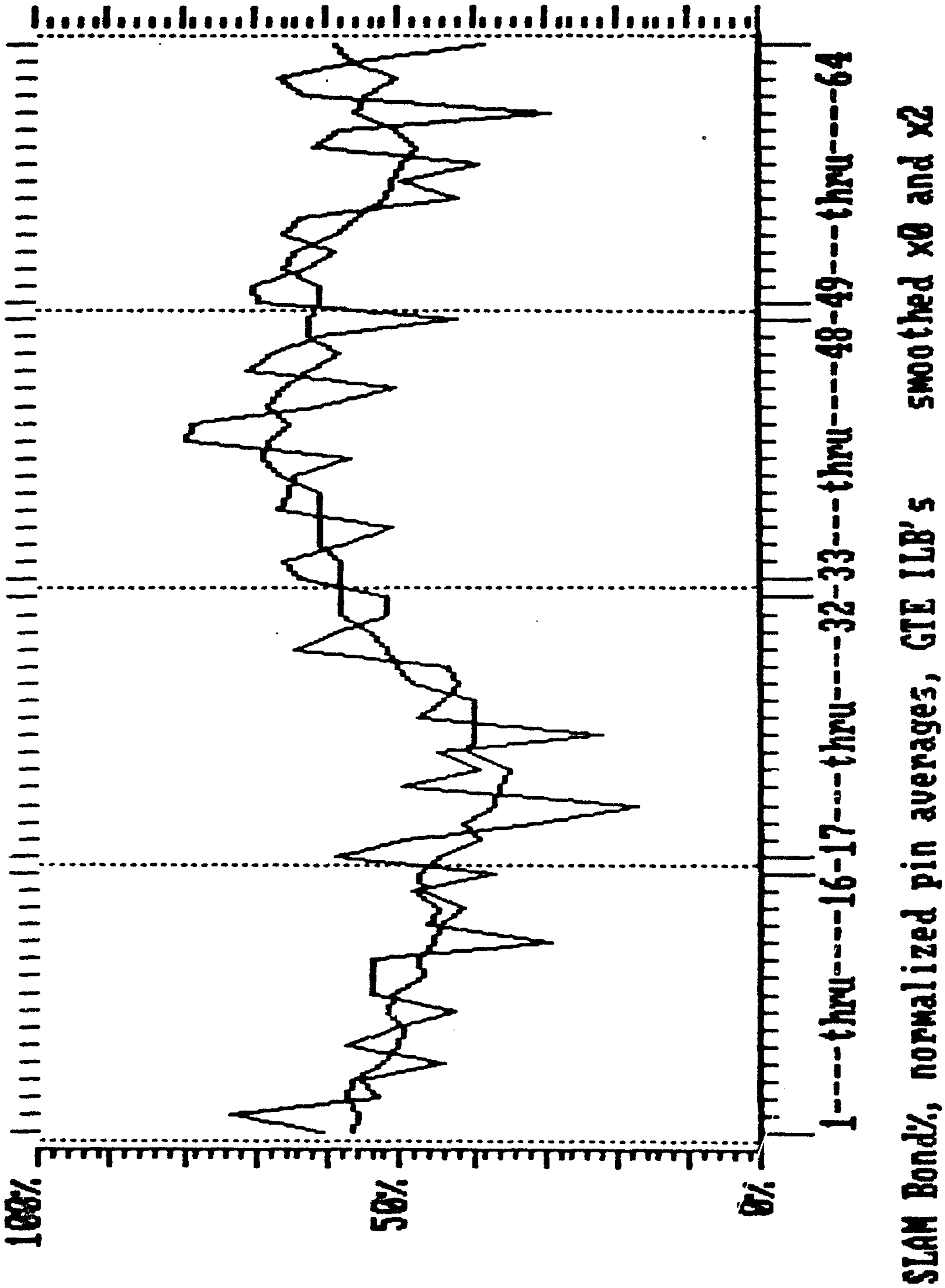


Figure B.2.17 SLAM Bond%, normalized pin averages, GTE ILBs smoothed x0,x2

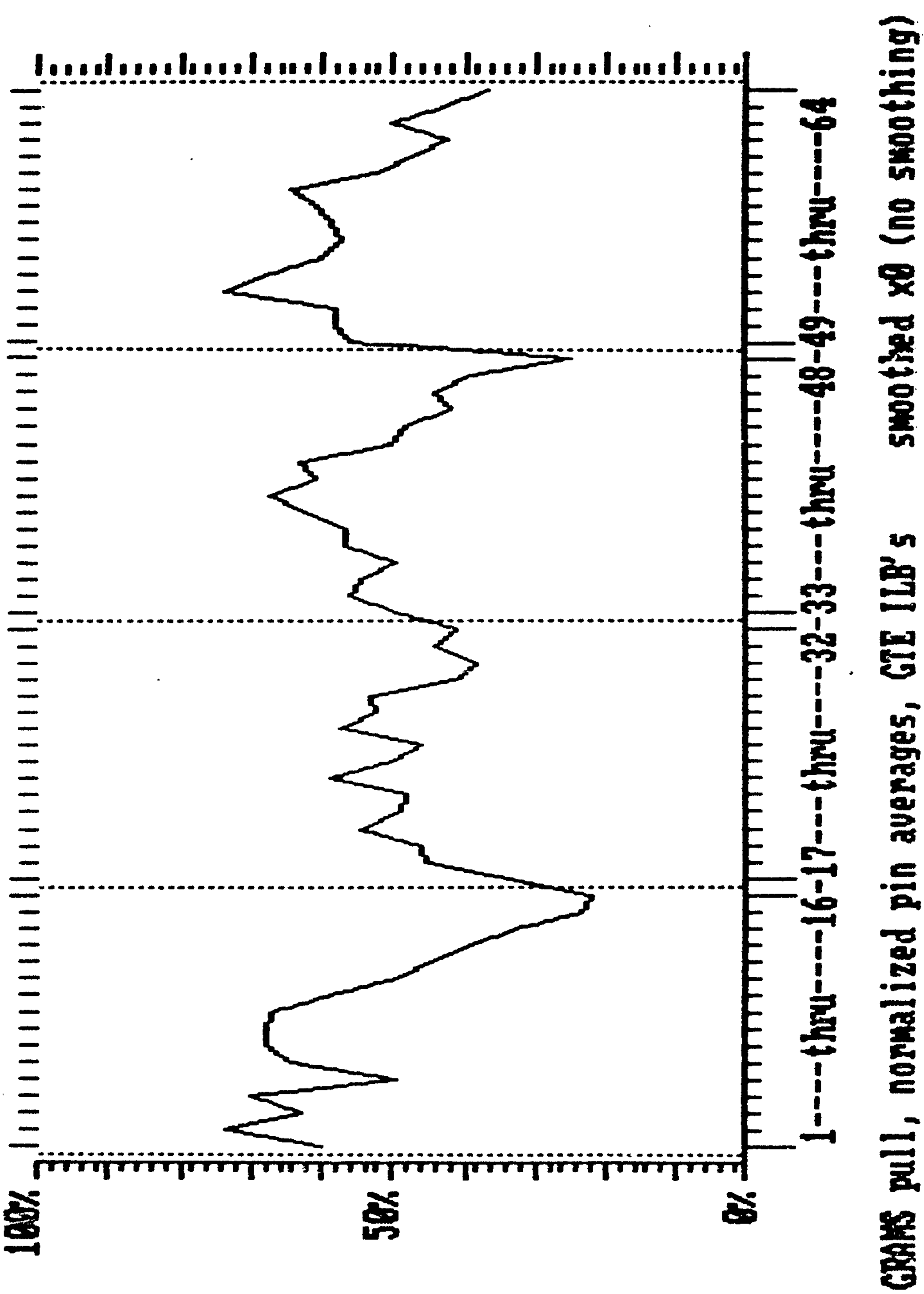


Figure B.2.13 Grams pull, normalized pin averages, GTE ILBs smoothed x0

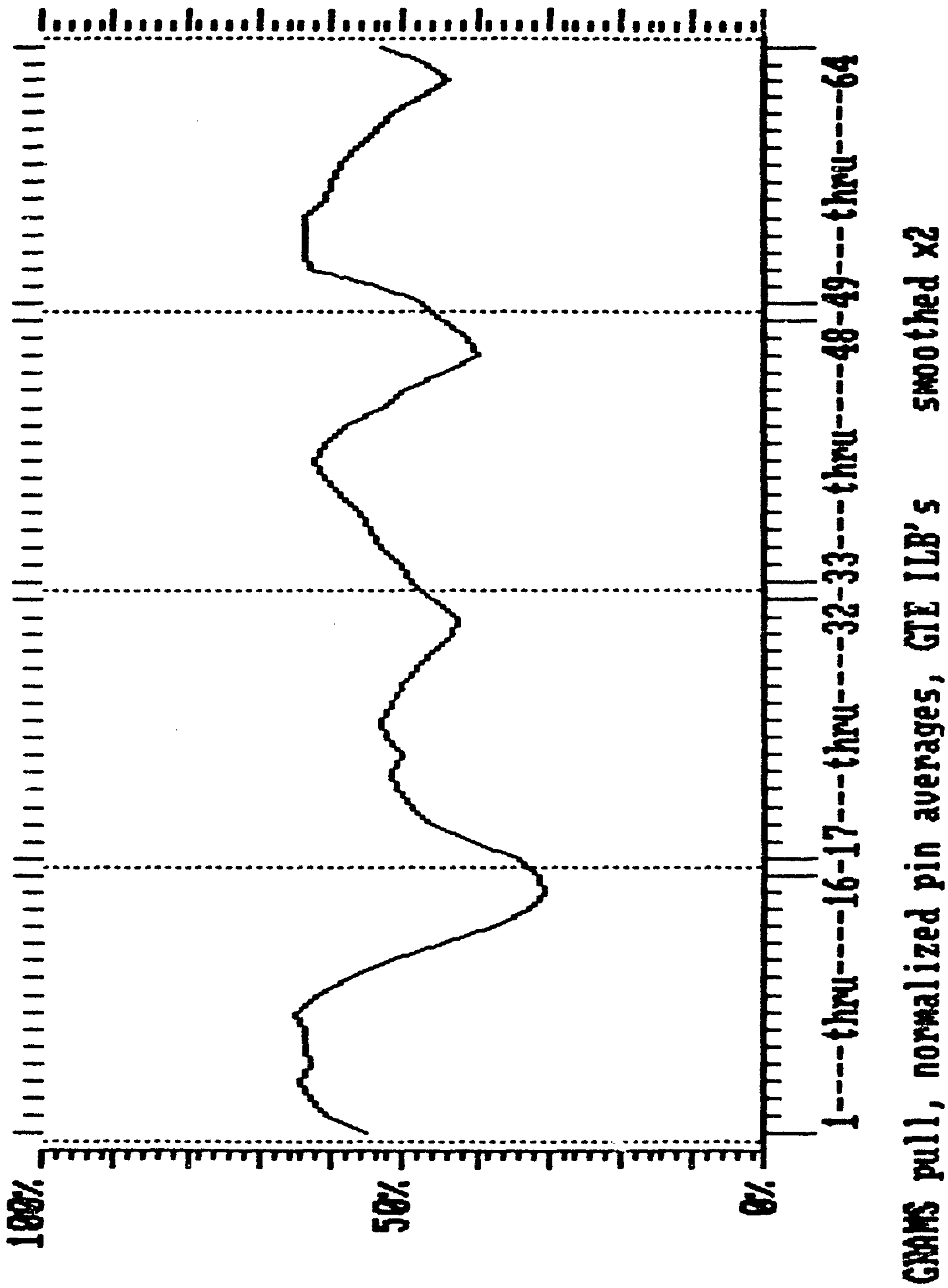


Figure B.2.19 Grams pull, normalized pin averages, GTE ILBs smoothed x2

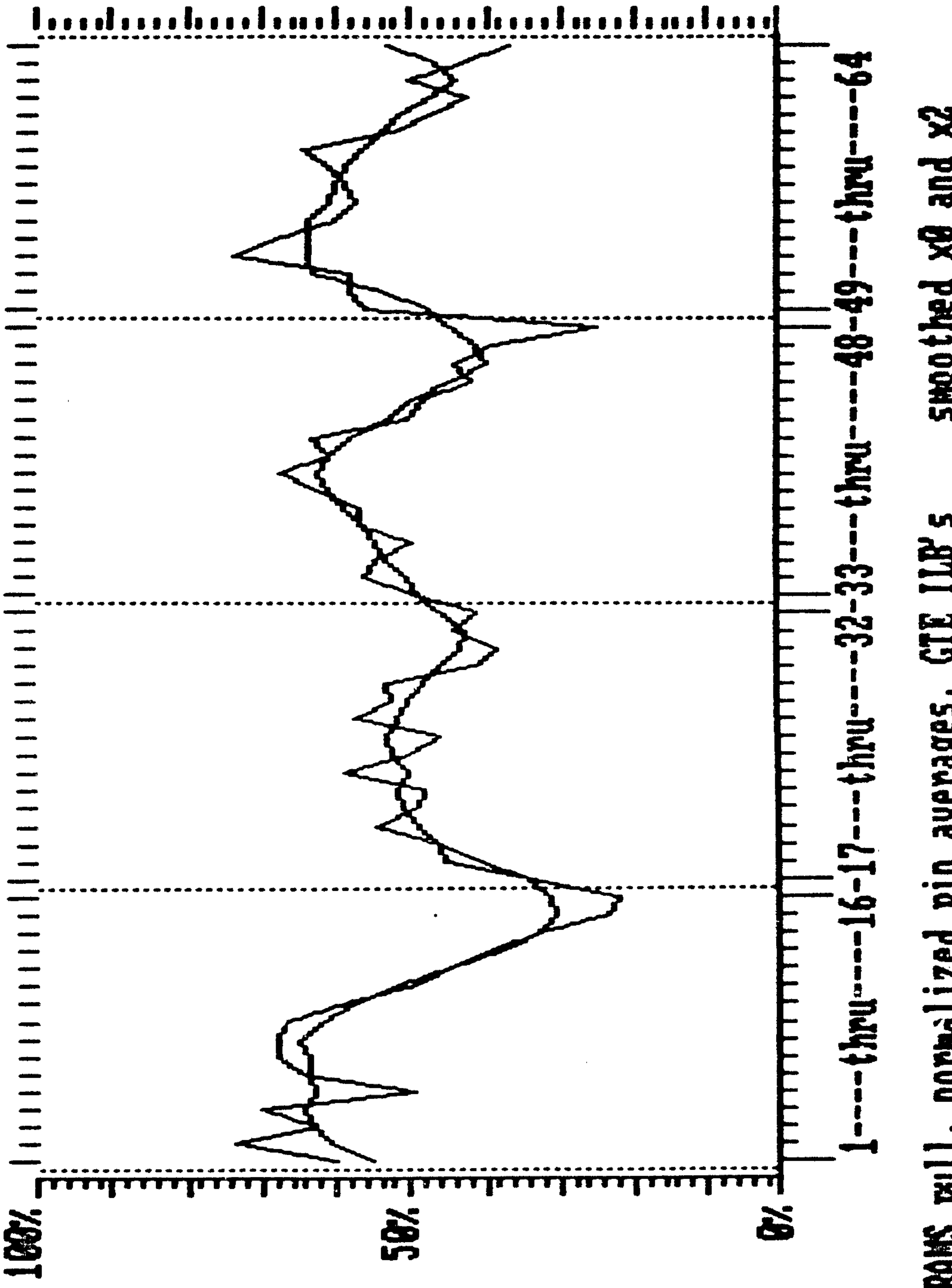


Figure B.2.20 Grams pull, normalized pin averages, GTE ILBs smoothed x0,x2

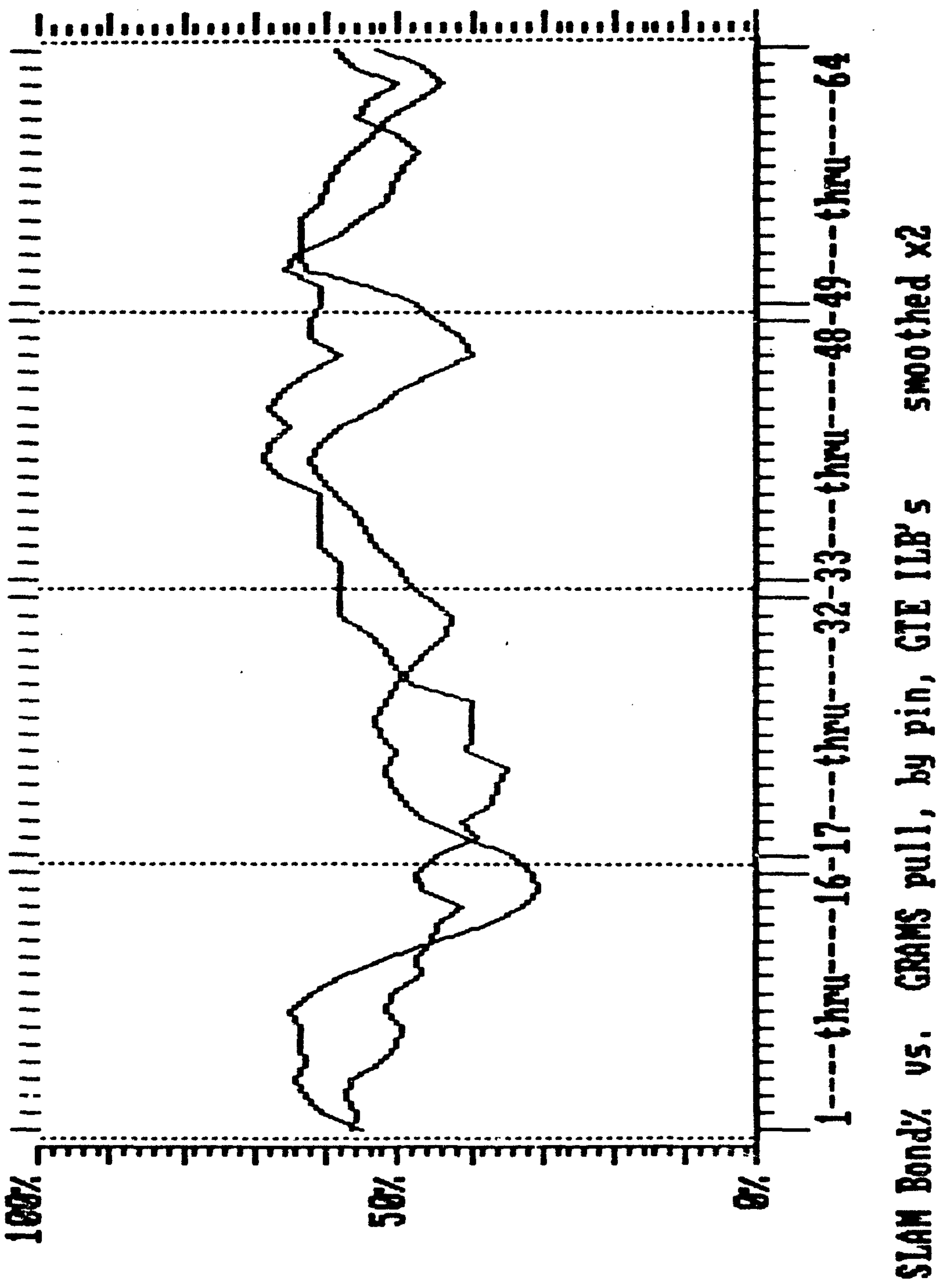


Figure B.2.21 SLAM Bond% vs Grams pull, by pin, GTE ILBs smoothed x2

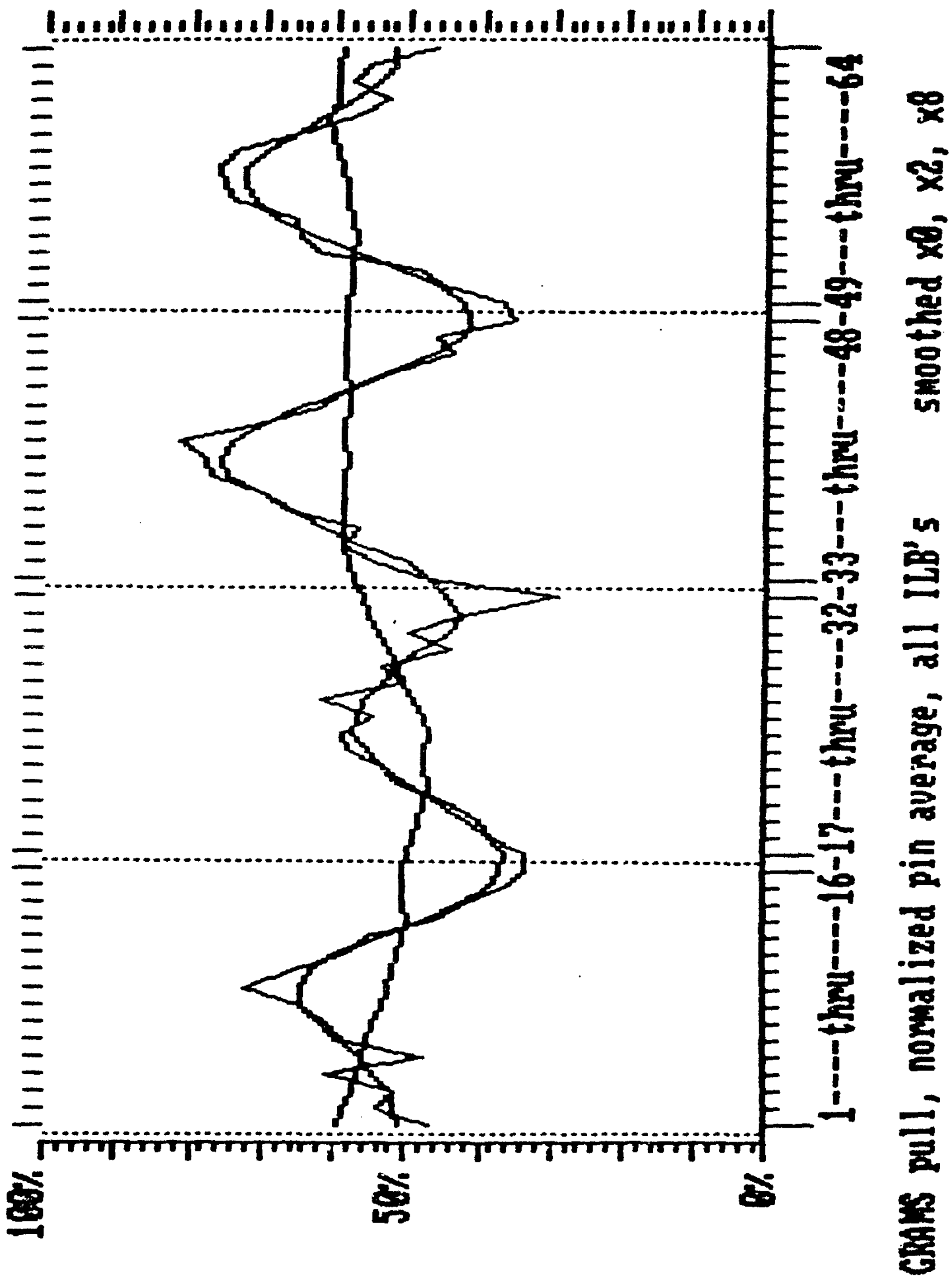


Figure B.2.22 Grams pull, normalized pin averages, all ILBs, smoothed x0,x2,x8

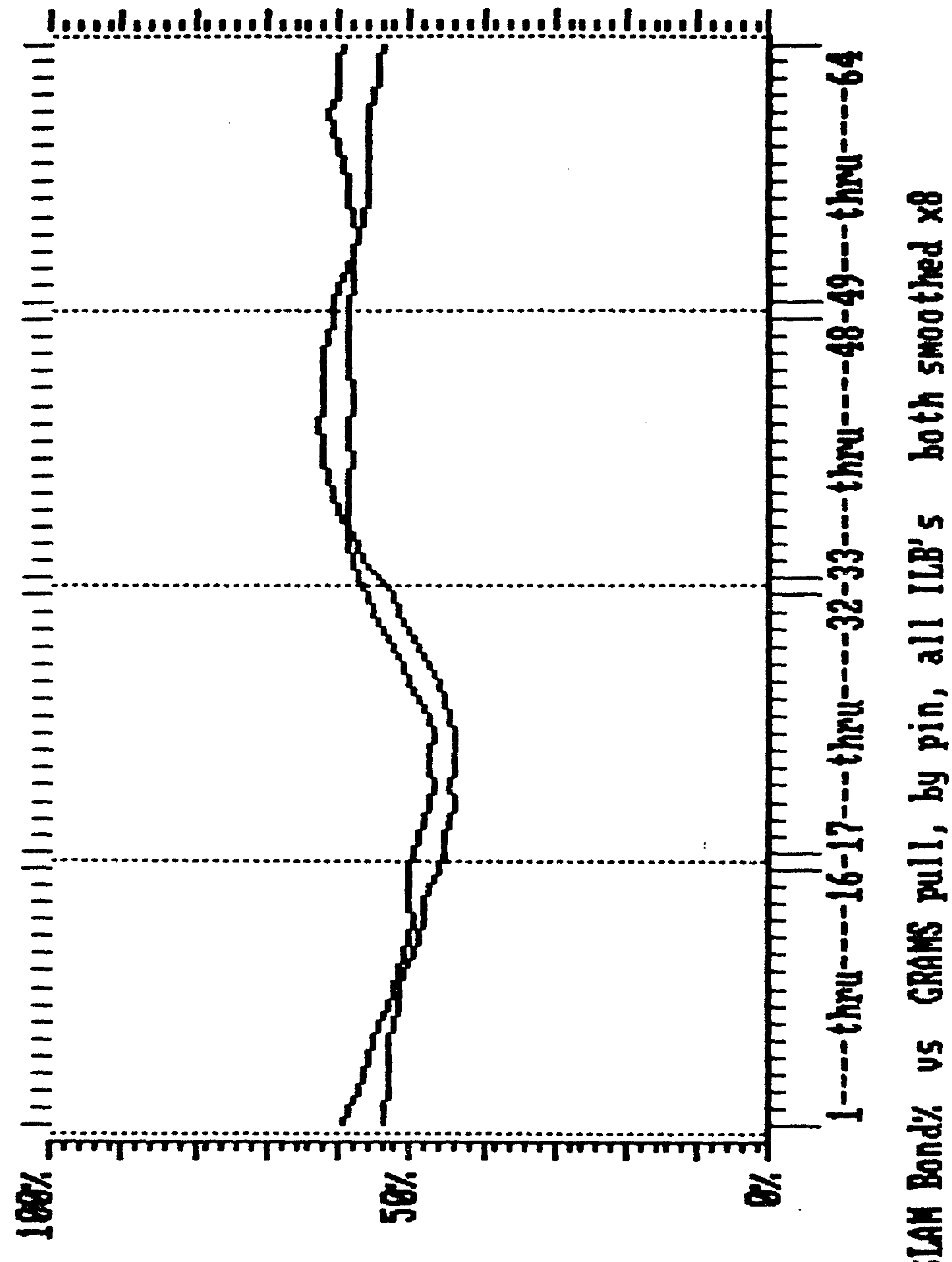


Figure B.2.23 SLAM Bond% and Grams pull, by pin, all ILBs, smoothed x2

Contents: Appendix "B" Section 3

Graphs pertinent to Periodic Effects
for OLB solder TAB samples.

—Covering all OLB's (pulled by Sonoscan or GTE)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

—Covering SS OLB's (pulled by Sonoscan only)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

—Covering GTE OLB's (pulled by GTE only)
- -SLAM Bond%, smoothed x0 (no smoothing)
- -SLAM Bond%, smoothed x2
- -SLAM Bond%, smoothed x0 and x2
- -GRAMS pull, smoothed x0 (no smoothing)
- -GRAMS pull, smoothed x2
- -GRAMS pull, smoothed x0 and x2
- -SLAM Bond% vs. GRAMS pull; smoothed x2

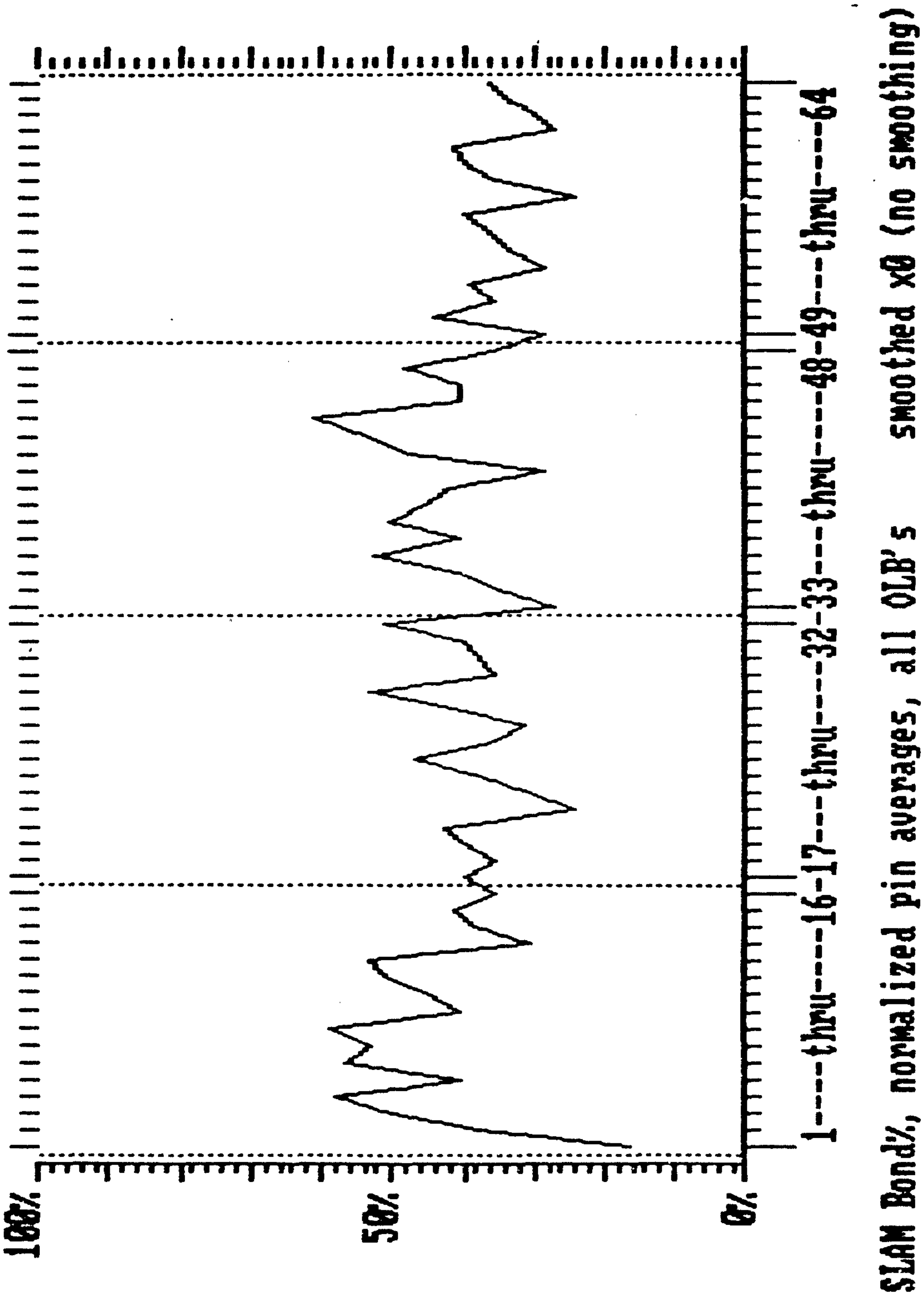


Figure B.3.1 SLAM Bond%, normalized pin averages, all OLBs smoothed x0

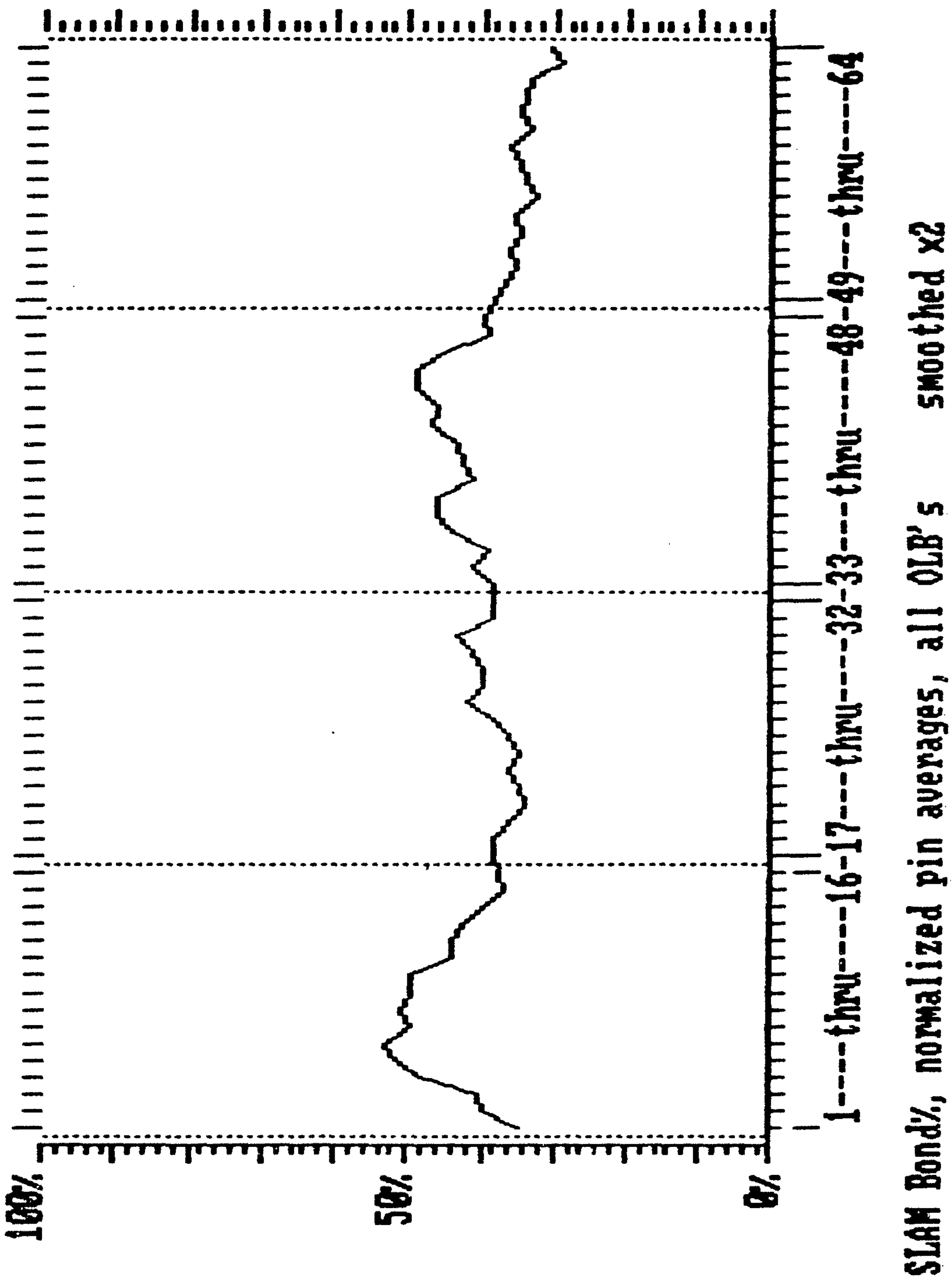


Figure B.3.2 SLAM Bond%, normalized pin averages, all OLBs smoothed x2

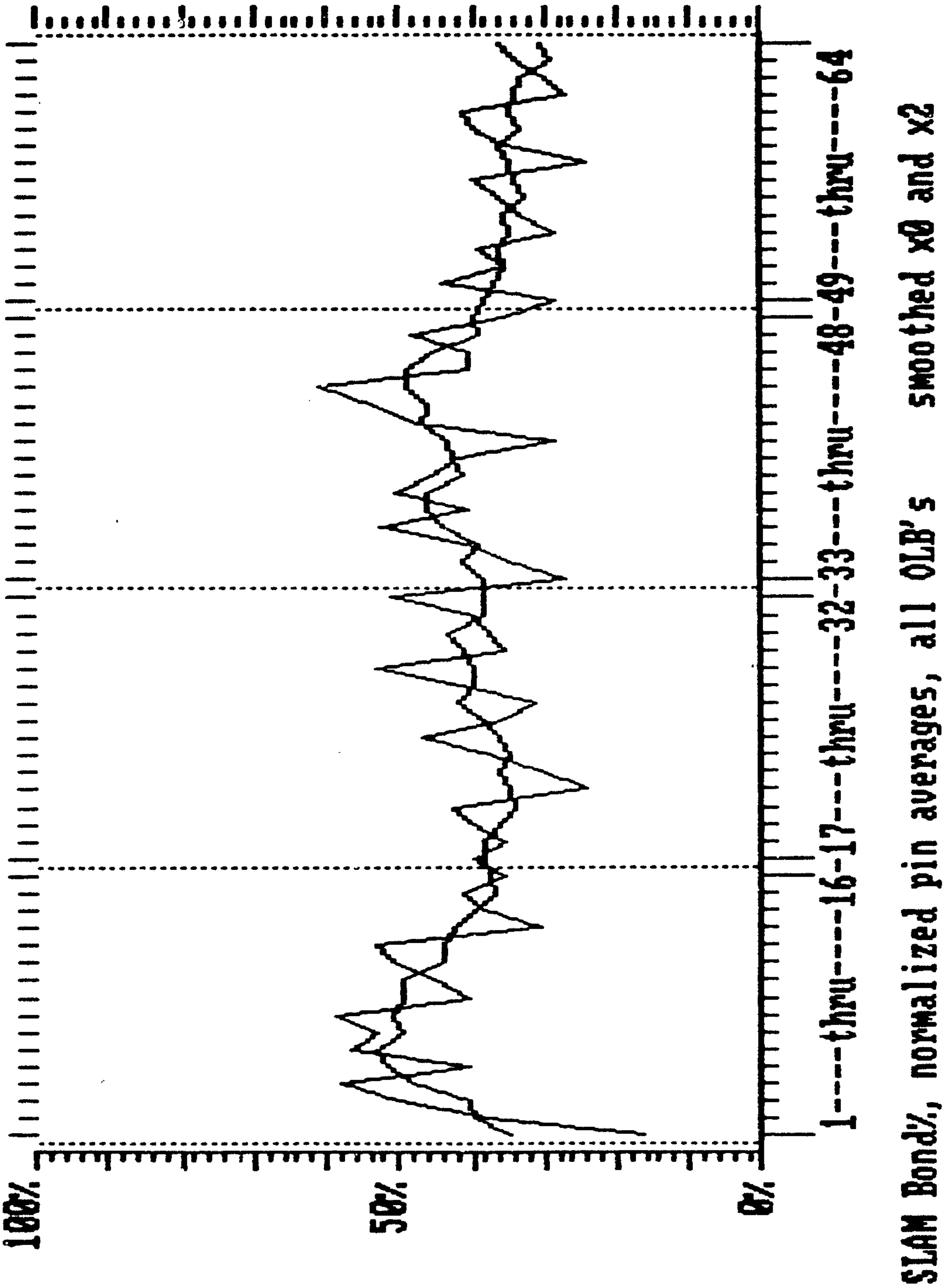


Figure B.3.3 SLAM Bond%, normalized pin averages, all OLBs smoothed x0,x2

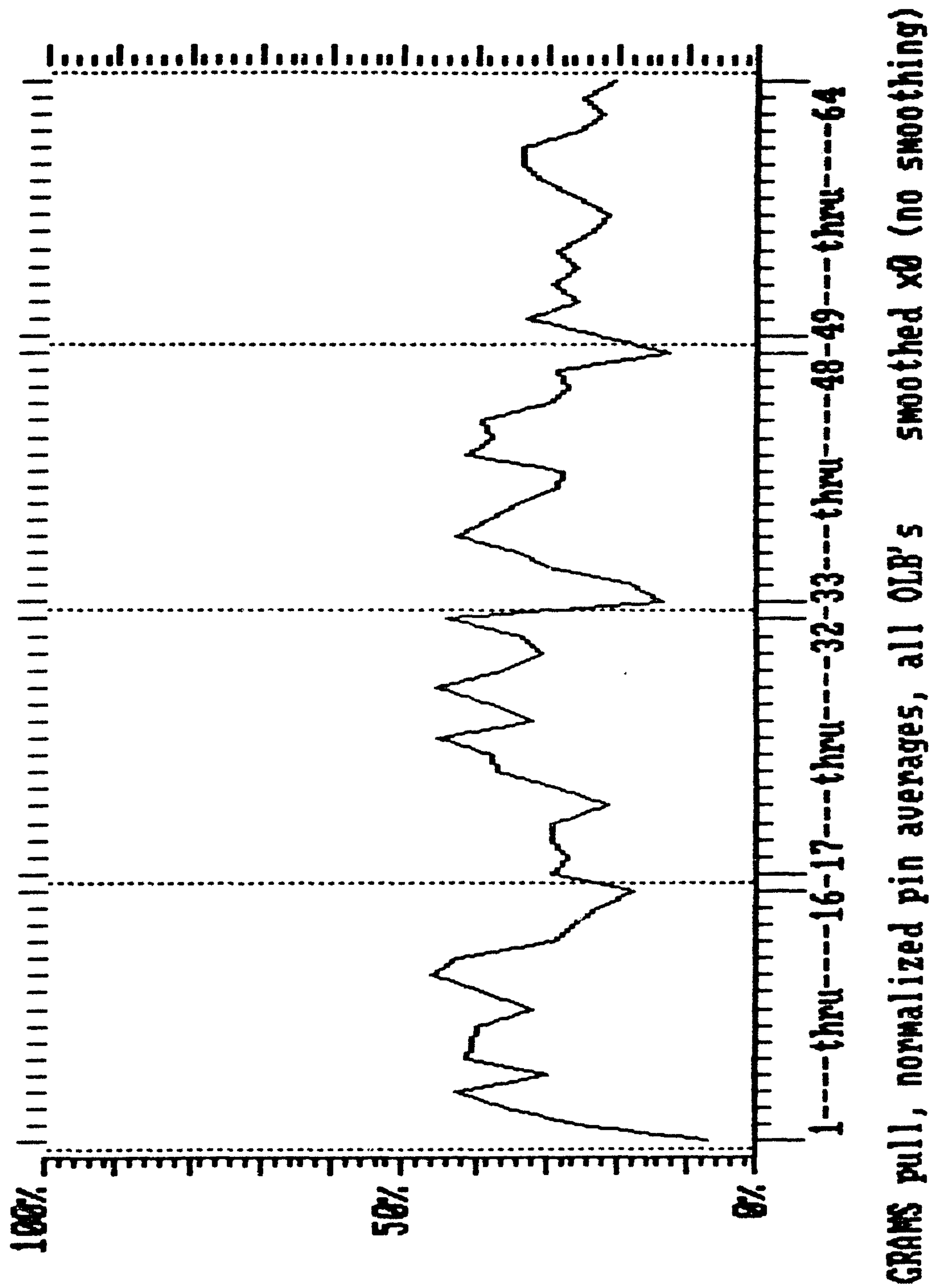


Figure B.3.4 Grams pull, normalized pin averages, all OLBs smoothed x0

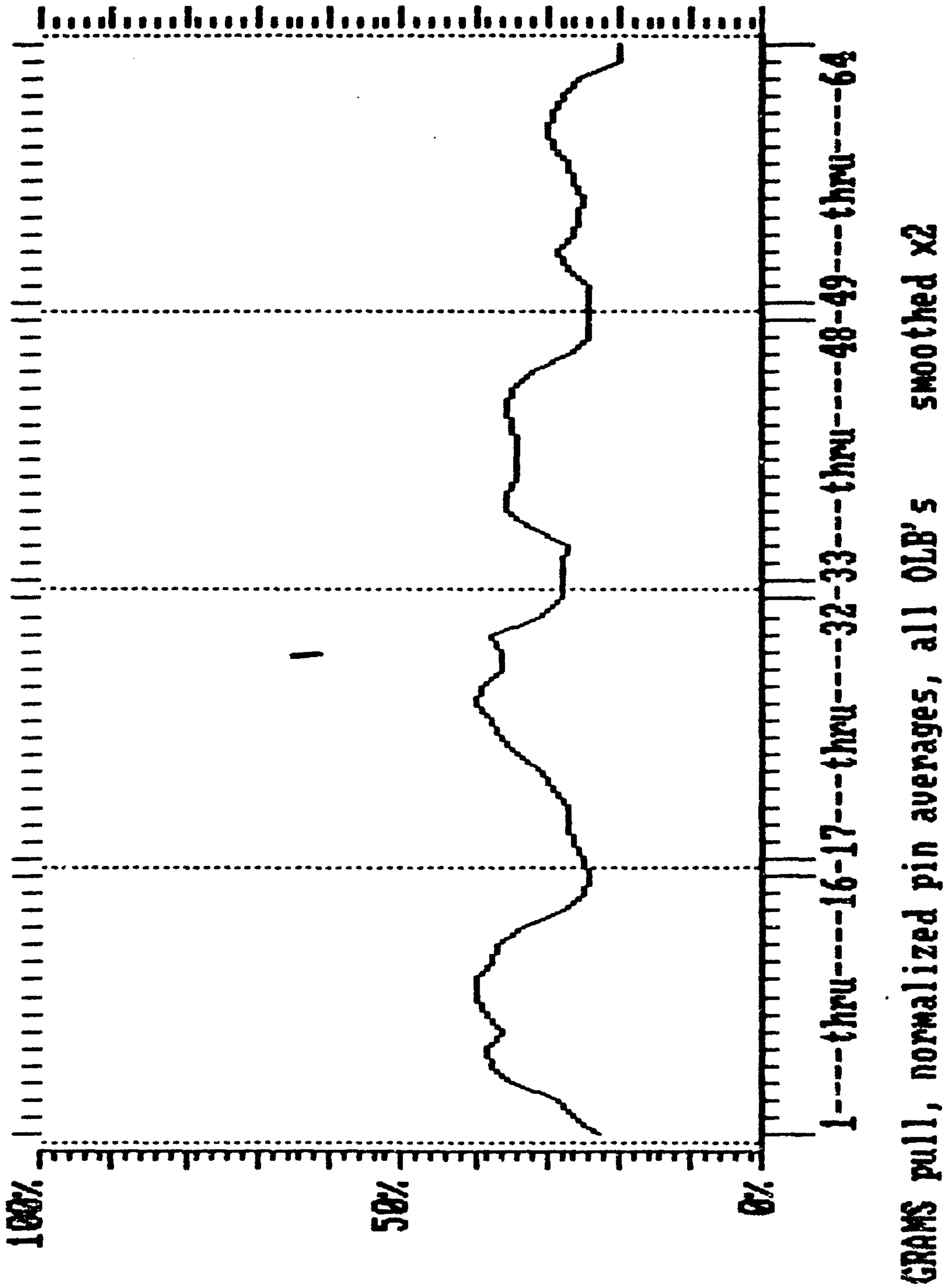


Figure B.3.5 Grams pull, normalized pin averages, all OLBs smoothed x2

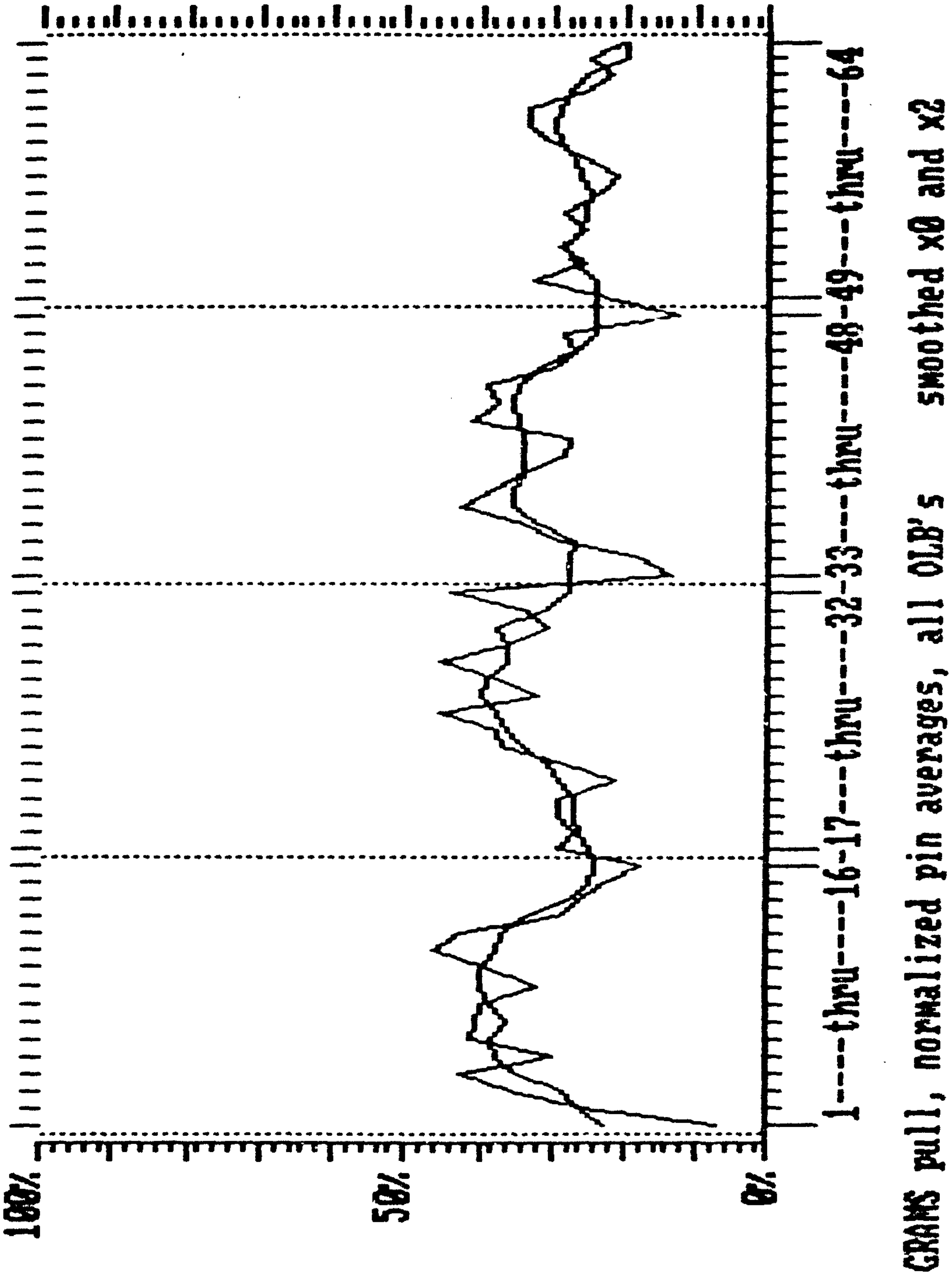


Figure B.3.6 Grams pull, normalized pin averages, all OLBs smoothed x0,x2

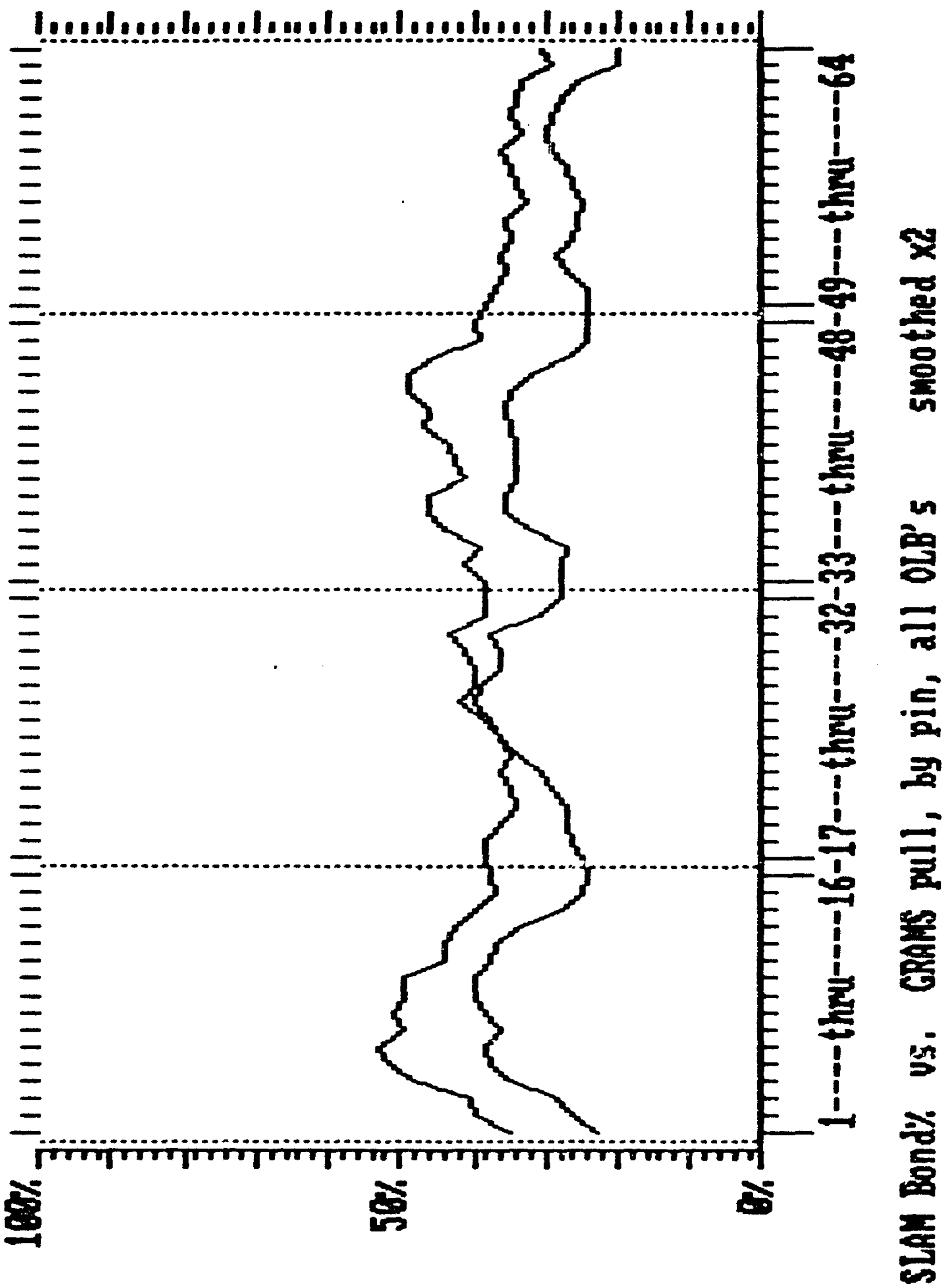


Figure B.3.7 SLAM Bond% vs Grams pull, by pin, all OLBs smoothed x2

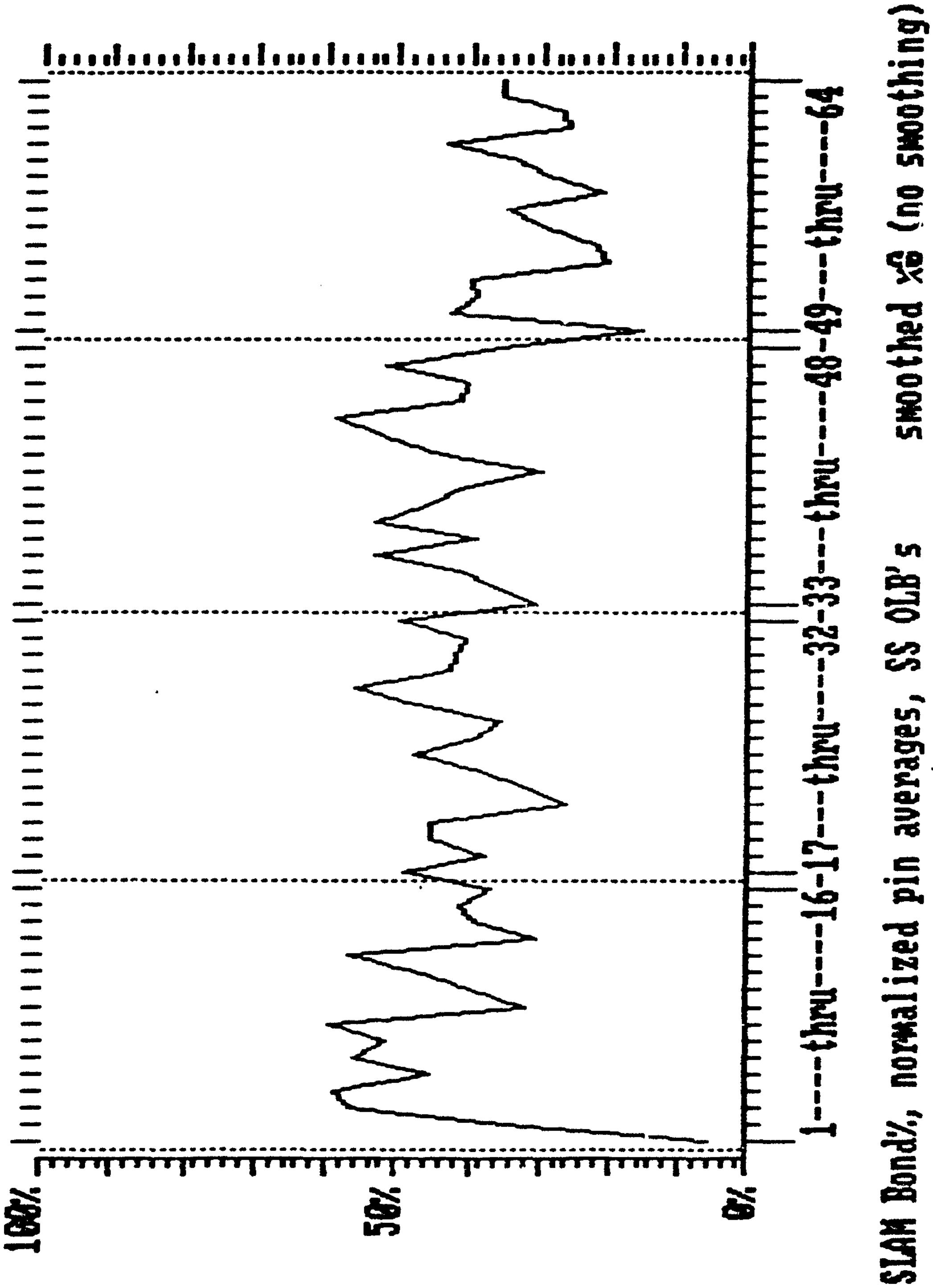


Figure B.3.8 SLAM Bond%, normalized pin averages, SS OLBs smoothed x0

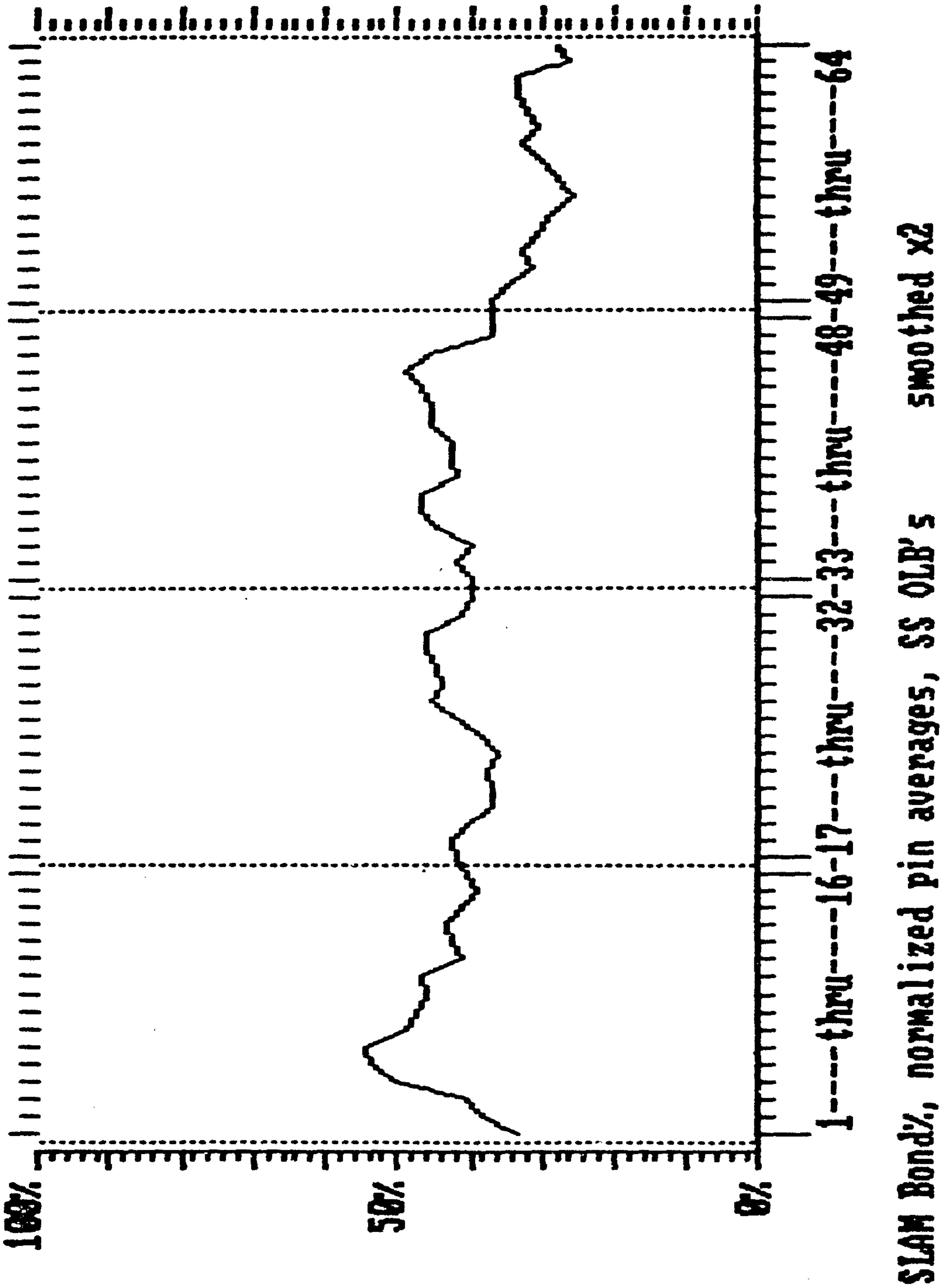


Figure B.3.9 SLAM Bond%, normalized pin averages, SS OLBs smoothed x2

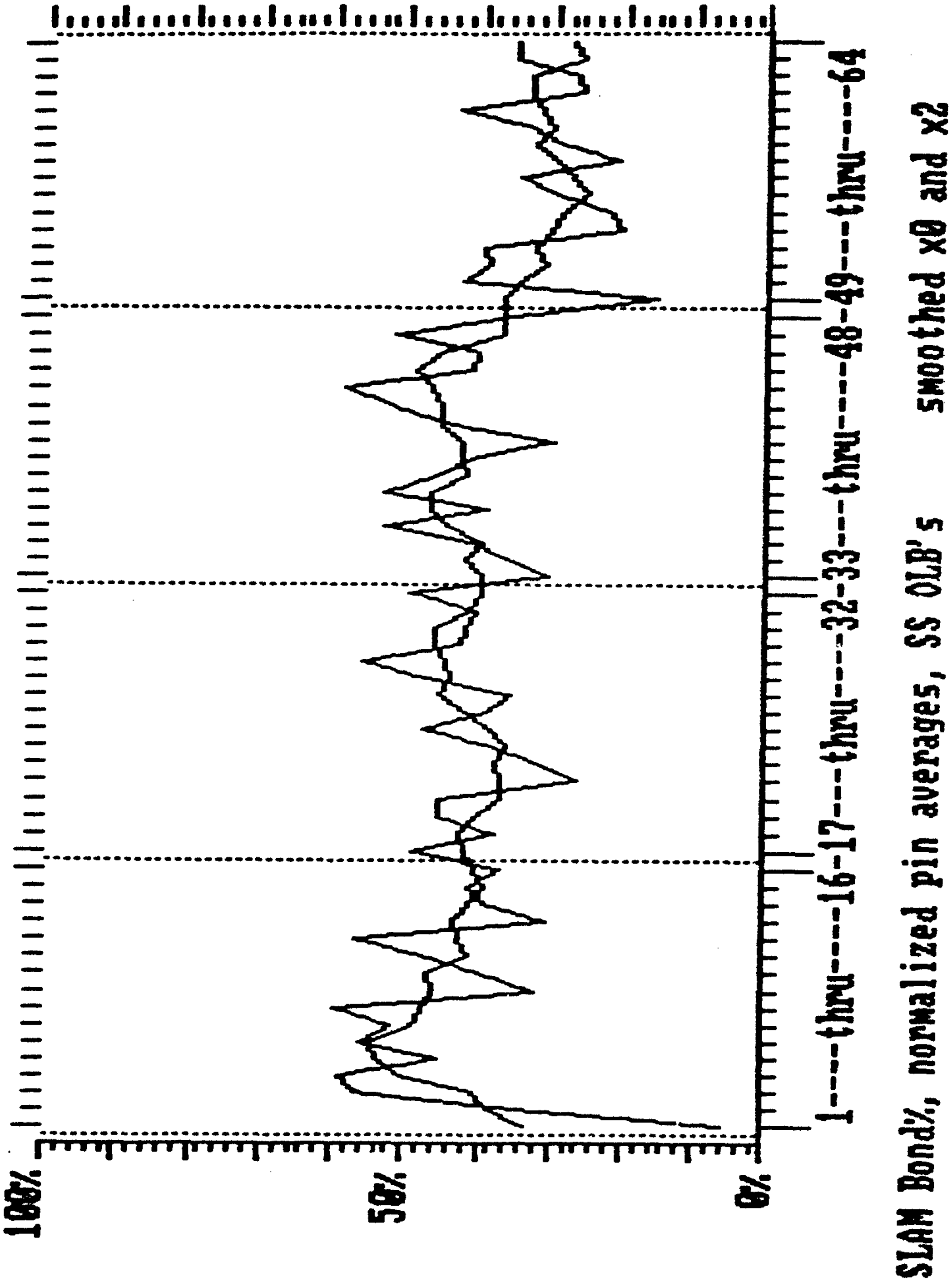


Figure B.3.10 SLAM Bond%, normalized pin averages, SS OLBs smoothed x0,x2

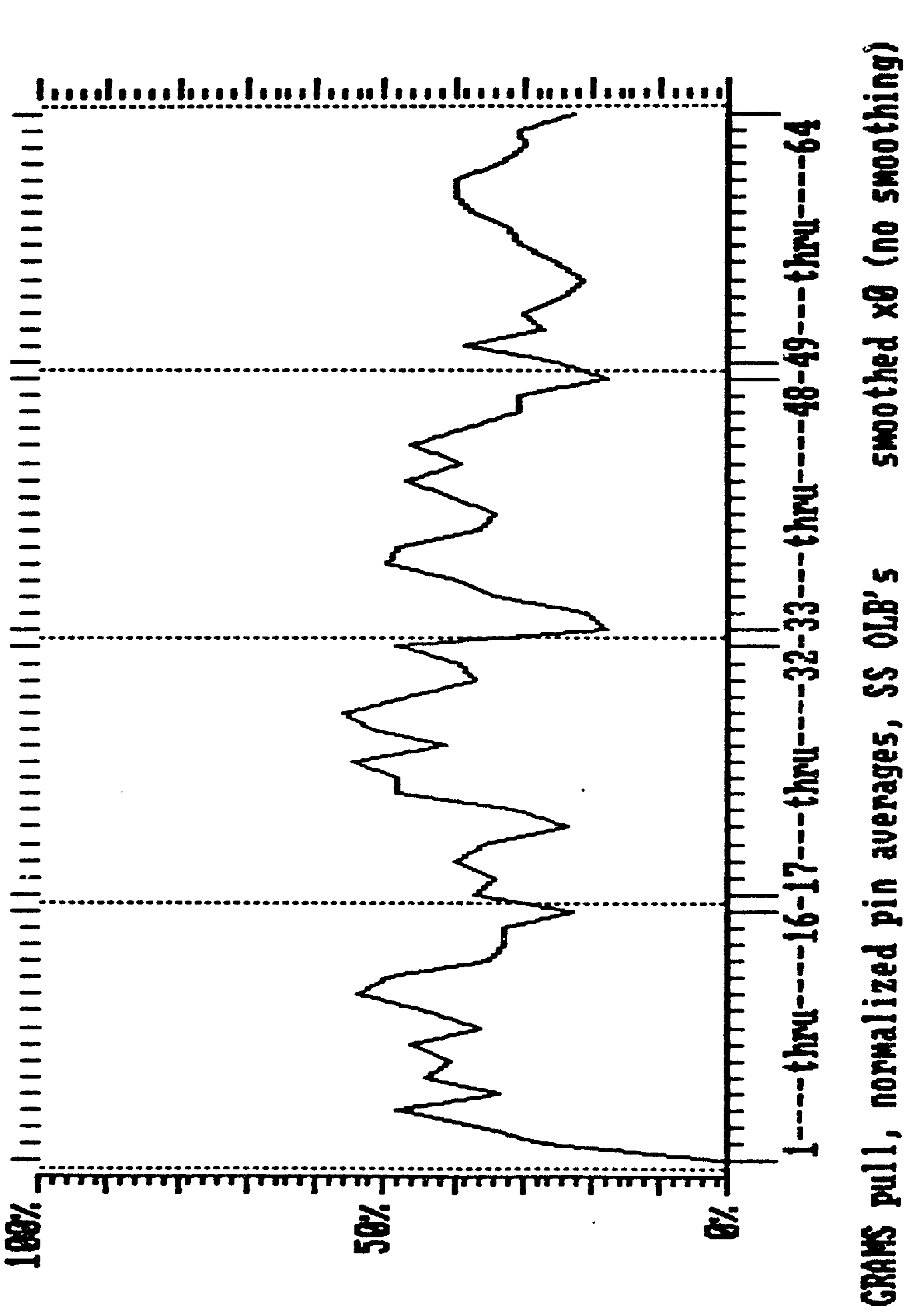


Figure B.3.11 Grams pull, normalized pin averages, SS OLBs smoothed x0

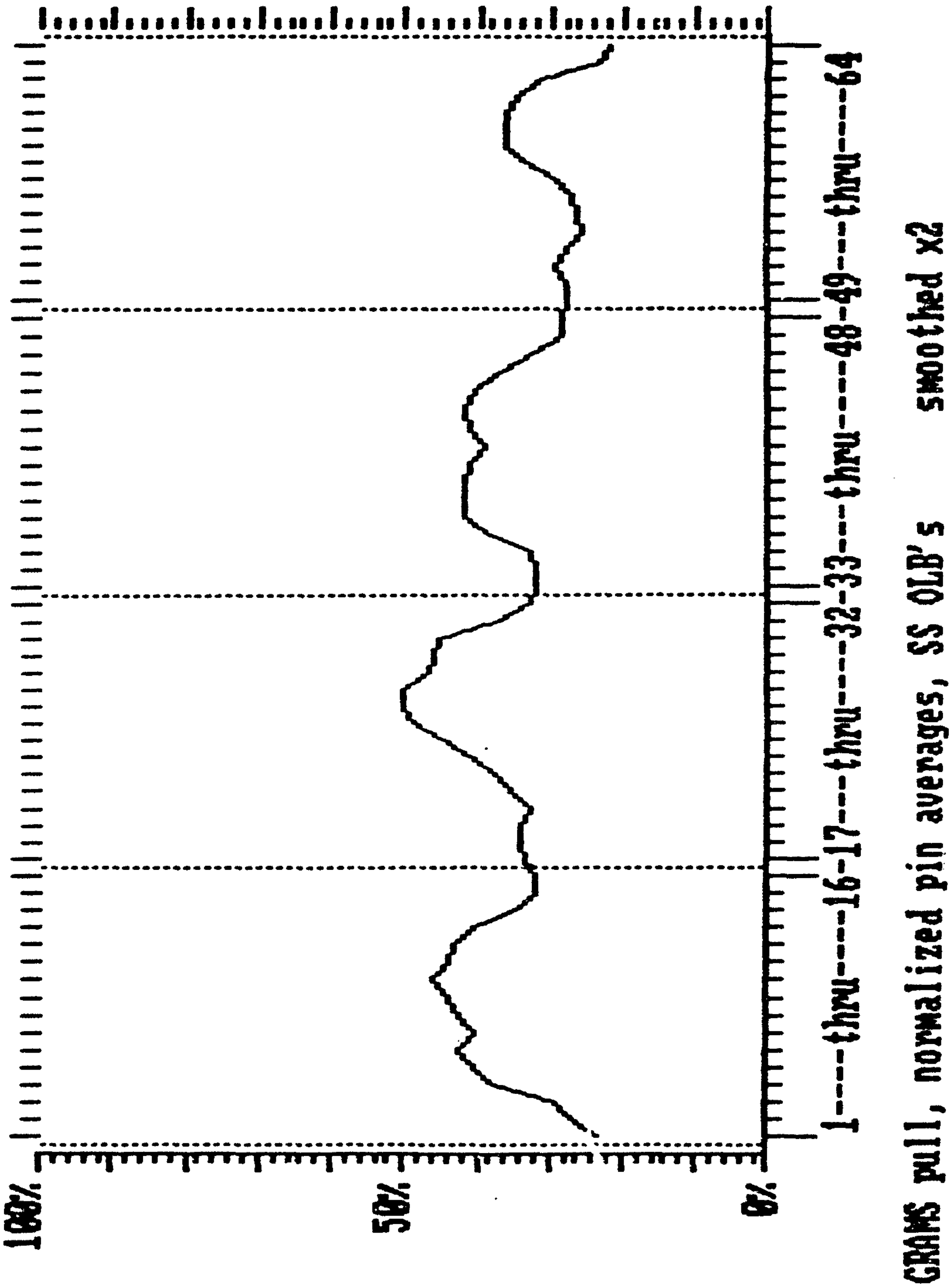


Figure B.3.12 Grams pull, normalized pin averages, SS OLBs smoothed x2

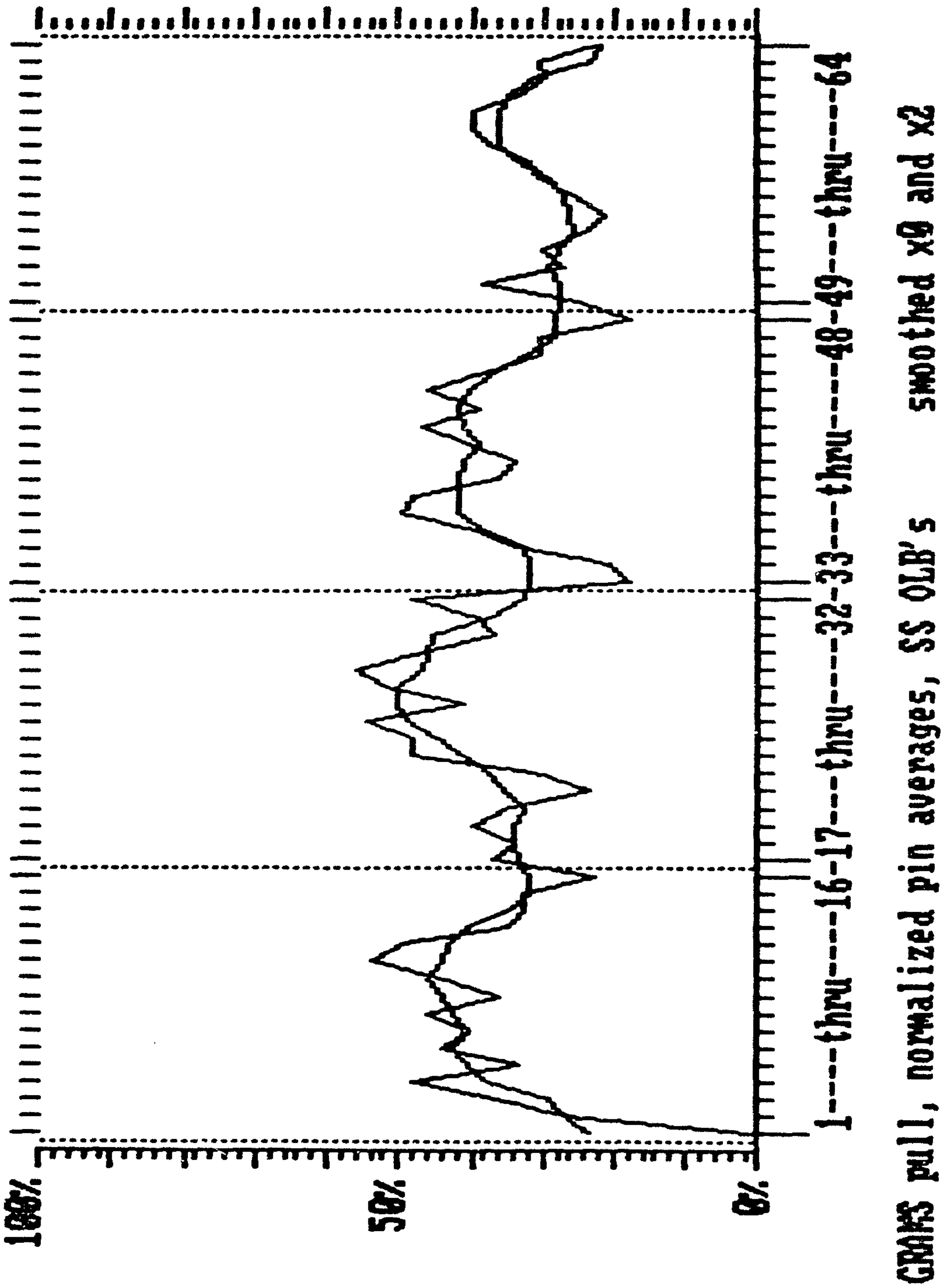


Figure B.3.13 Grams pull, normalized pin averages, SS OLBs smoothed x0,x2

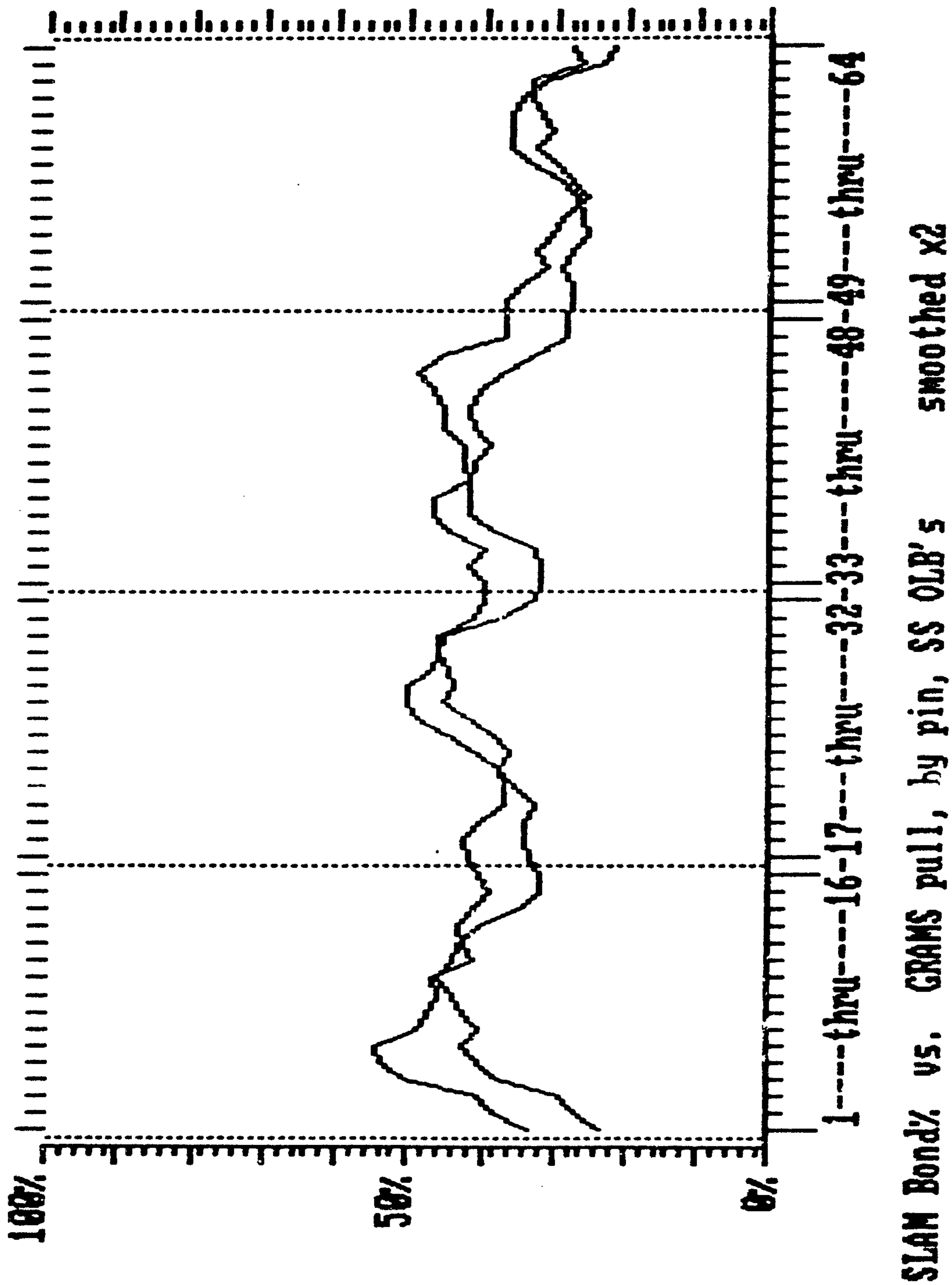


Figure B.3.14 SLAM Bond% vs Grams pull, by pin, SS OLBs smoothed x2

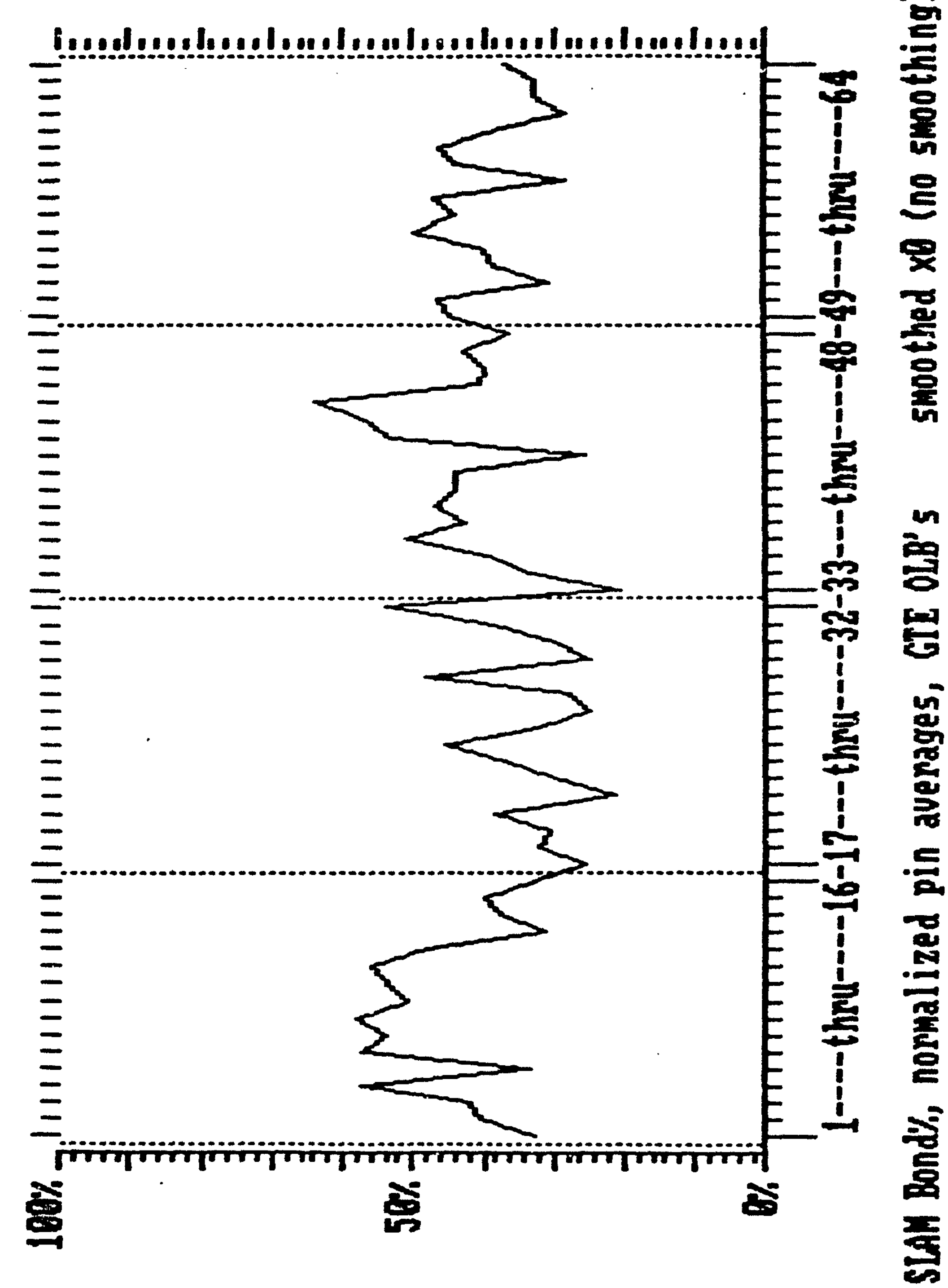


Figure B.3.15 SLAM Bond%, normalized pin averages, GTE OLBs smoothed x0

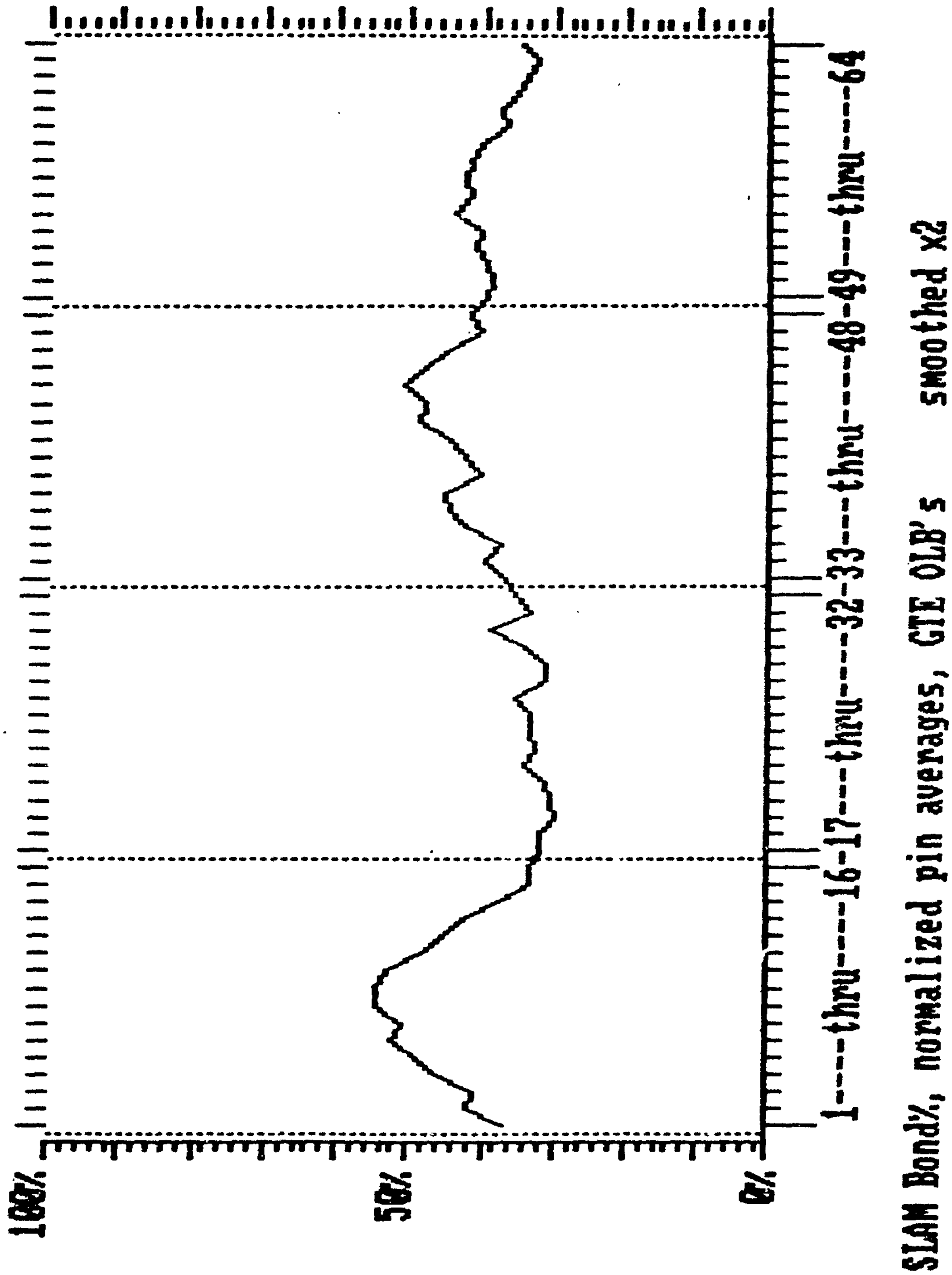


Figure B.3.16 SLAM Bond%, normalized pin averages, GTE OLBs smoothed x2

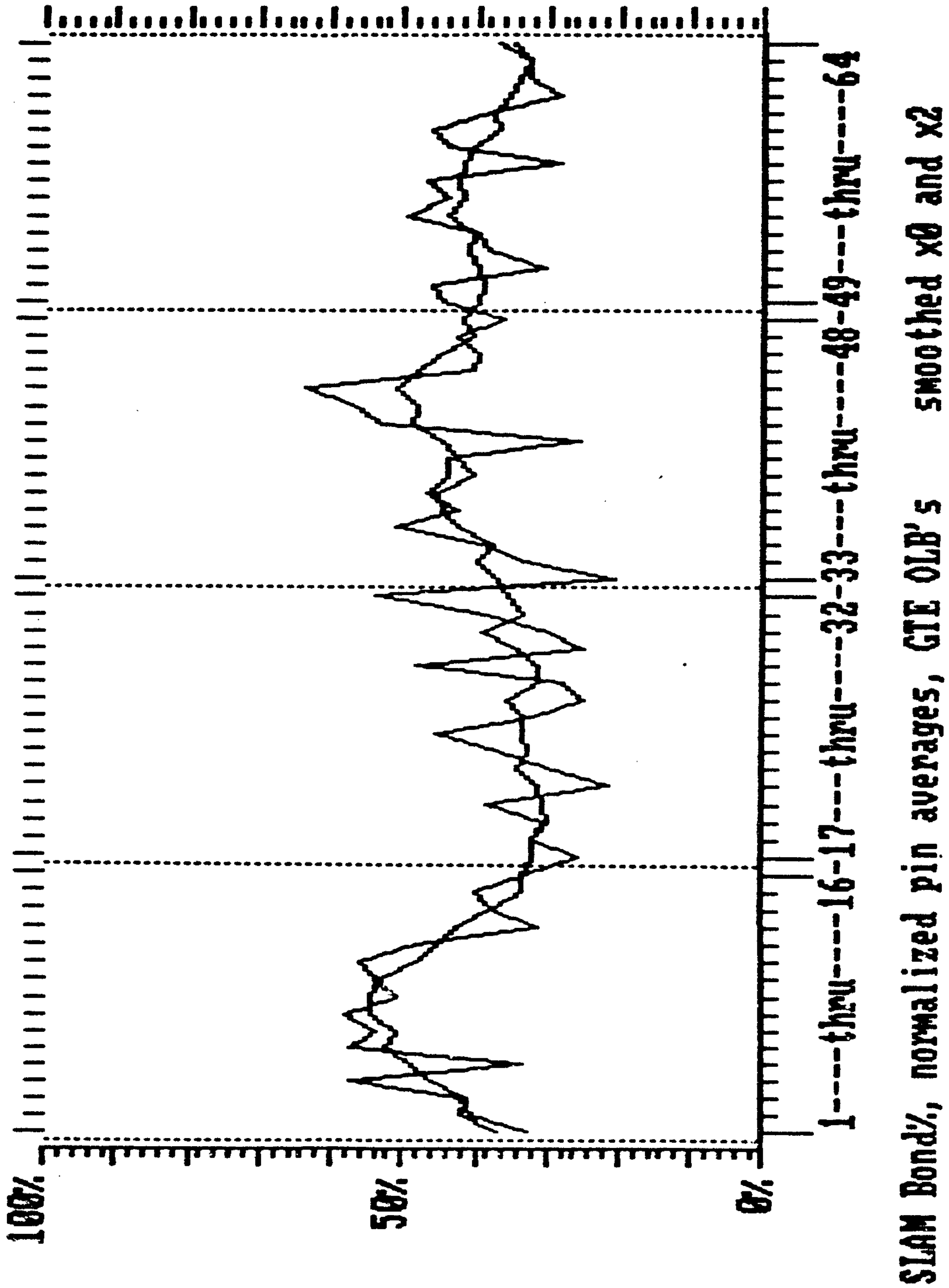


Figure B.3.17 SLAM Bond%, normalized pin averages, GTE OLBs smoothed x0,x2

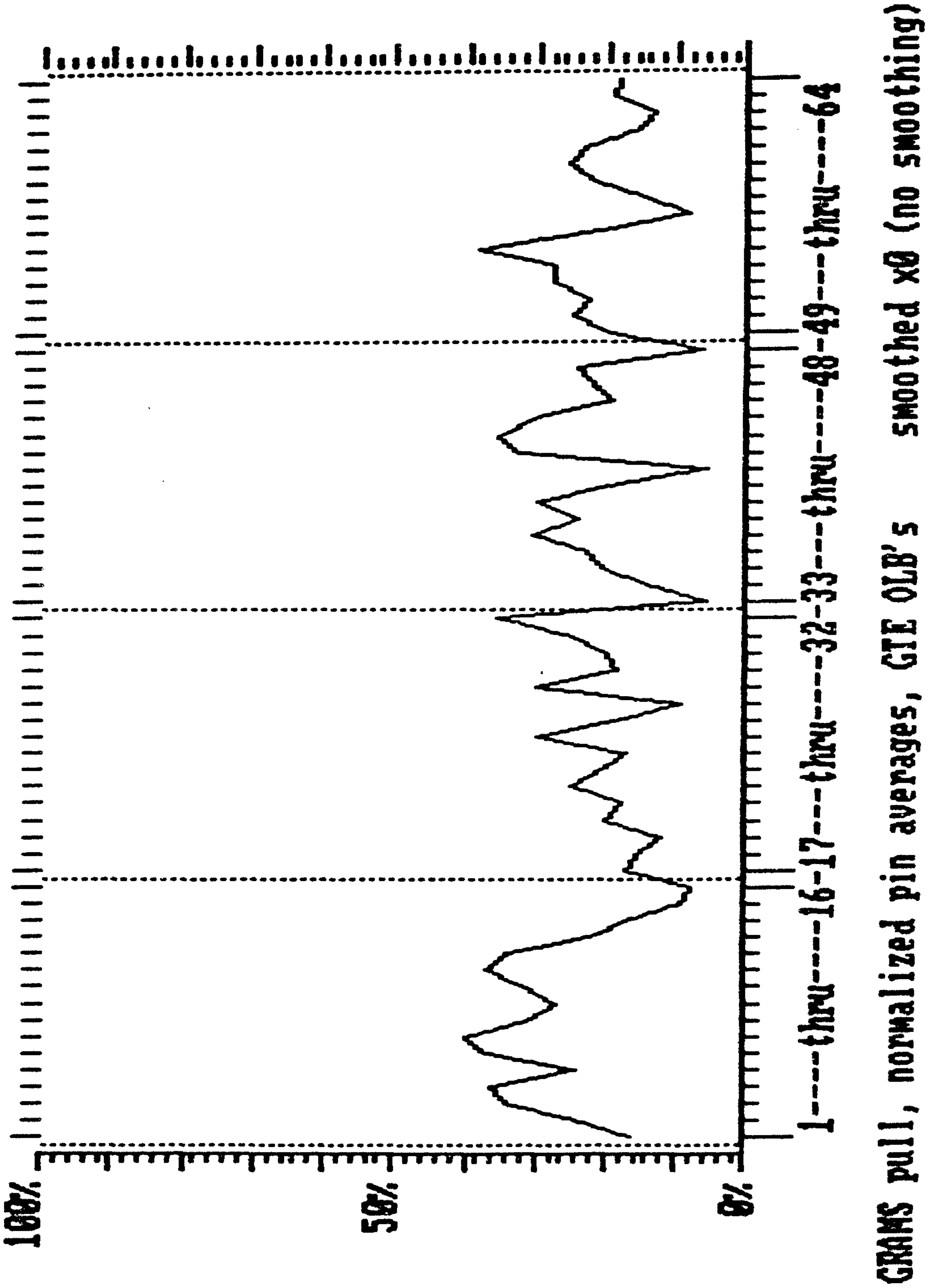


Figure B.3.18 Grams pull, normalized pin averages, GTE OLBs smoothed x0

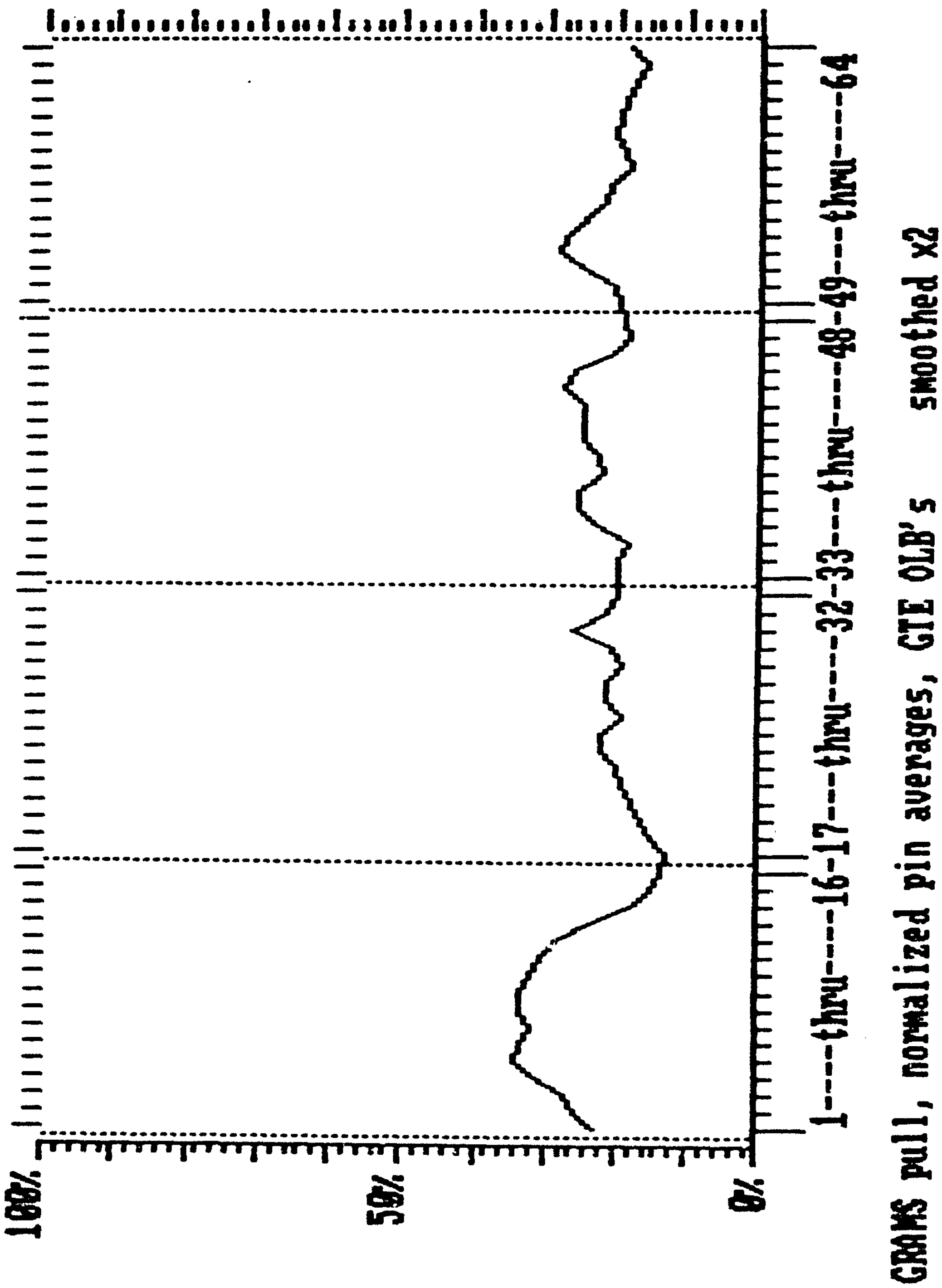


Figure B.3.19 Grams pull, normalized pin averages, GTE OLBs smoothed x2

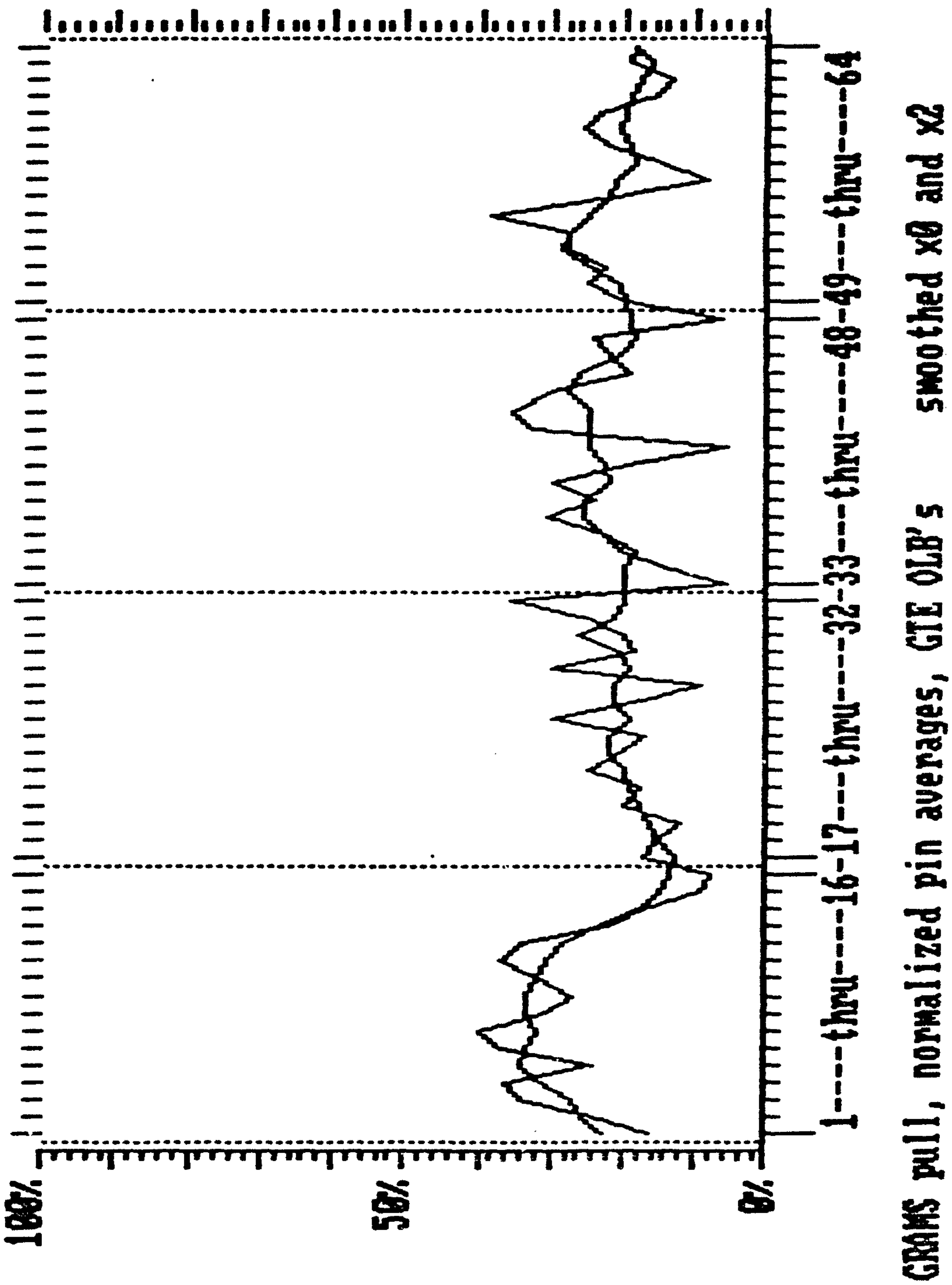


Figure B.3.20 Grams pull, normalized pin averages, GTE OLBs smoothed x0,x2

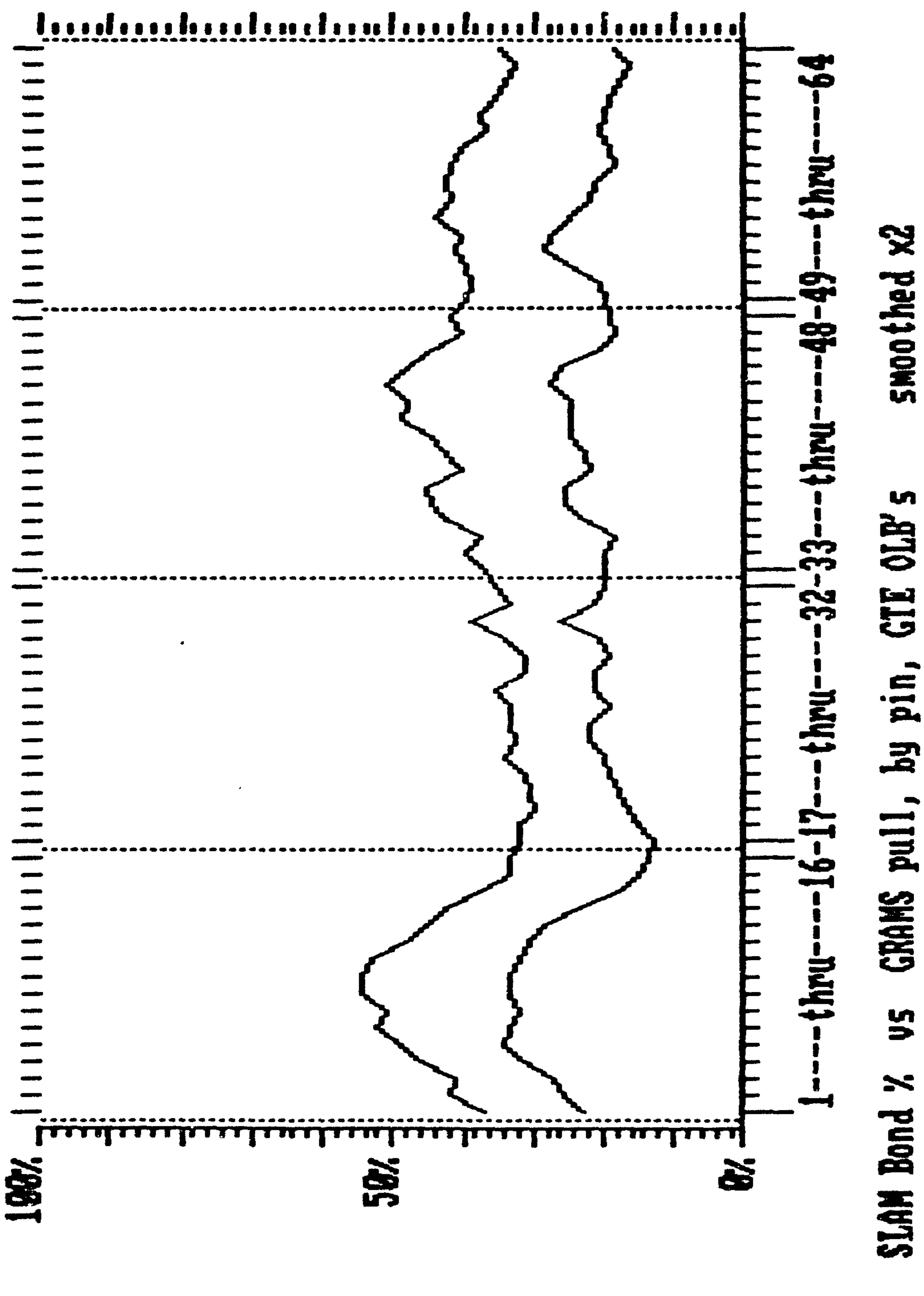


Figure B.3.21 SLAM Bond% vs Grams pull, by pin, GTE OLBs smoothed x2

Contents: Appendix "B" Section 4

Graphs pertinent to Periodic Effects
for MESA ILB Au-Au and Au-Sn TAB samples.

—Covering all samples (pulled by Sonoscan)
-SLAM Bond%, smoothed x0 (no smoothing)
-SLAM Bond%, smoothed x2
-SLAM Bond%, smoothed x0 and x2
-GRAMS pull, smoothed x0 (no smoothing)
-GRAMS pull, smoothed x2
-GRAMS pull, smoothed x0 and x2
-SLAM Bond% vs. GRAMS pull; smoothed x2

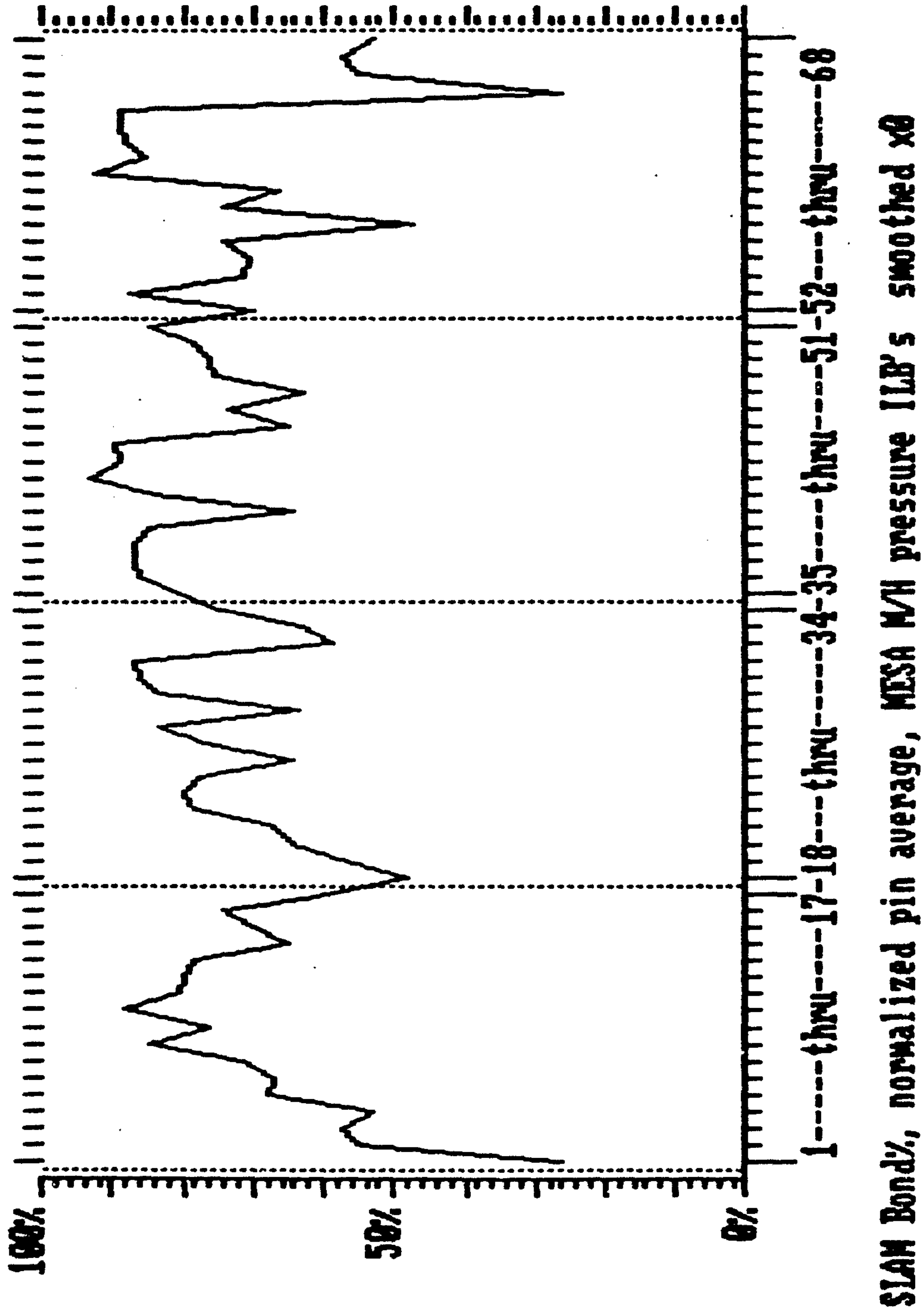


Figure B.4.1 SLAM Bond%, normalized pin averages, MESA ILBs smoothed x0

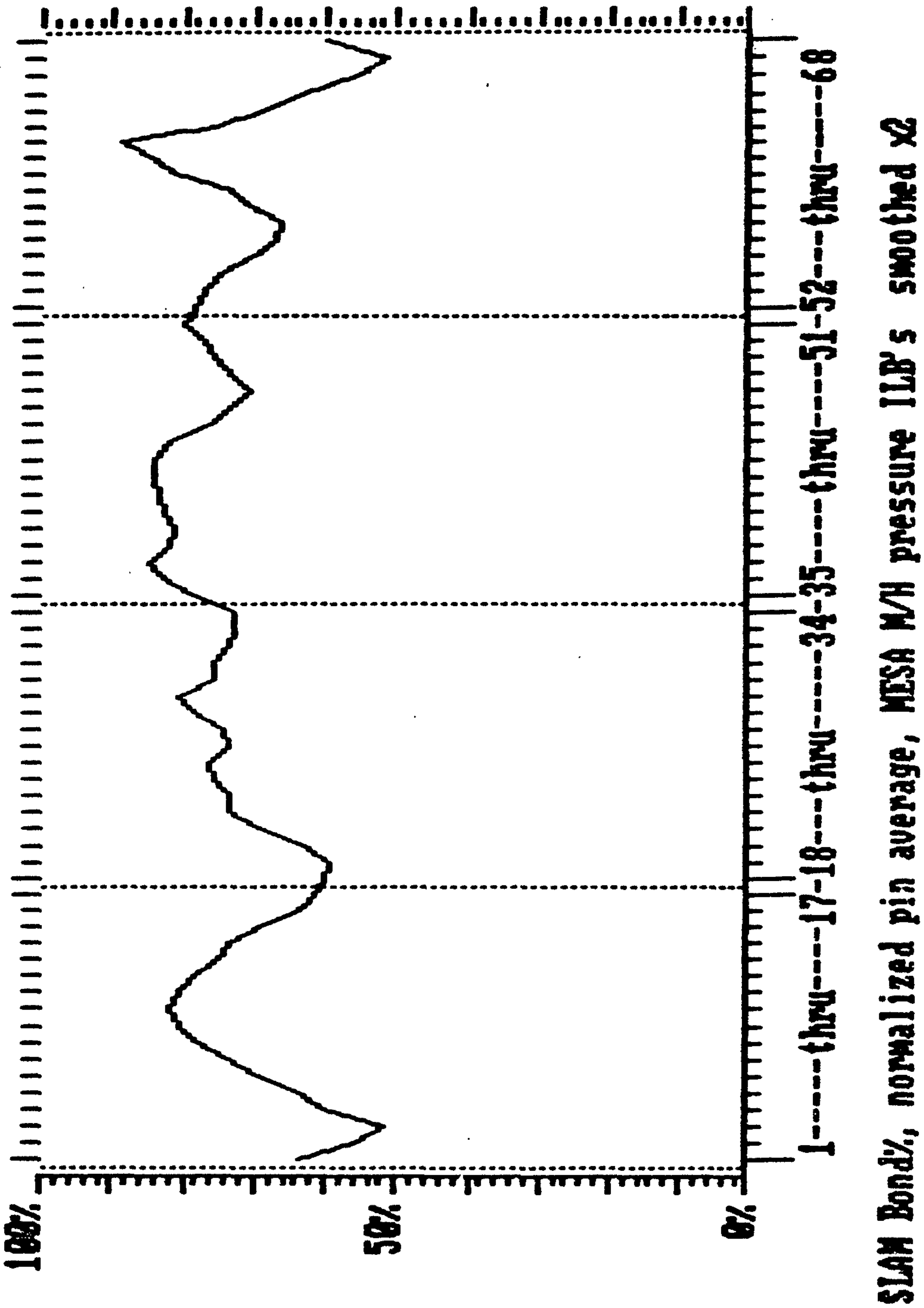


Figure B.4.2 SLAM Bond%, normalized pin averages, MESA ILBs smoothed x2

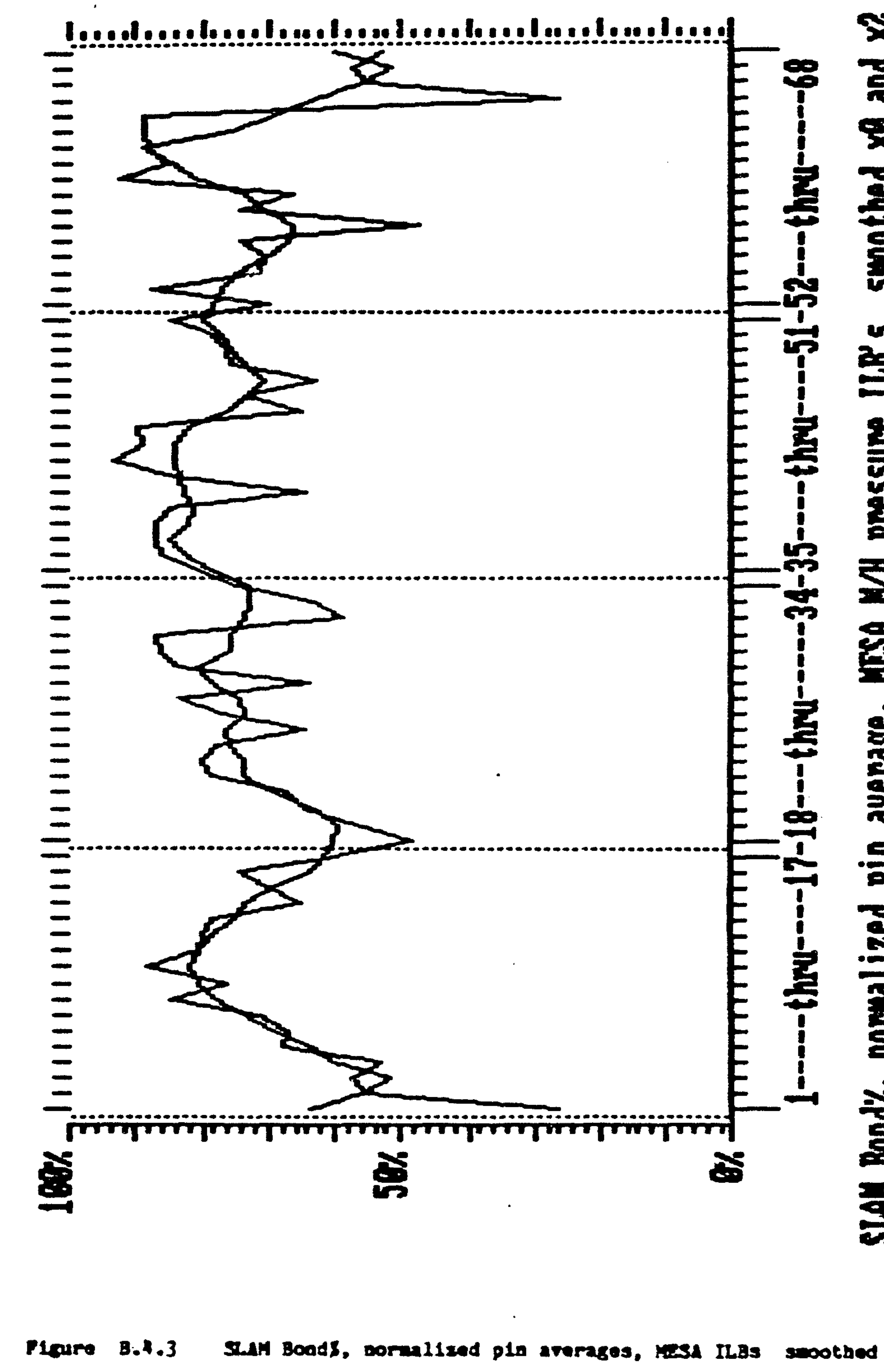


Figure B.4.3 SLAM Bond%, normalized pin averages, MESA ILBs smoothed x0,x2

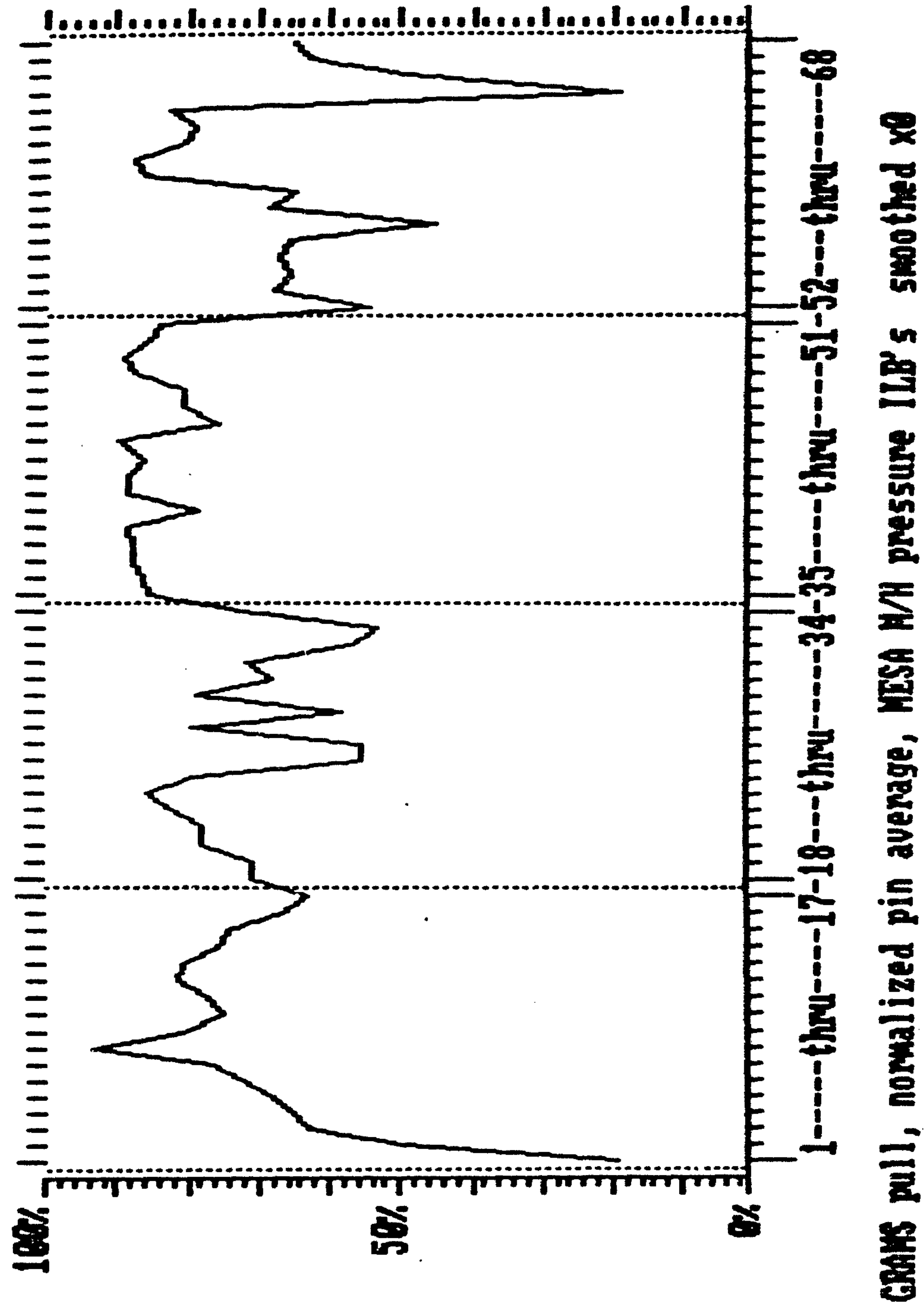


Figure B.4.4 Grams pull, normalized pin averages, MESA ILBs smoothed x0

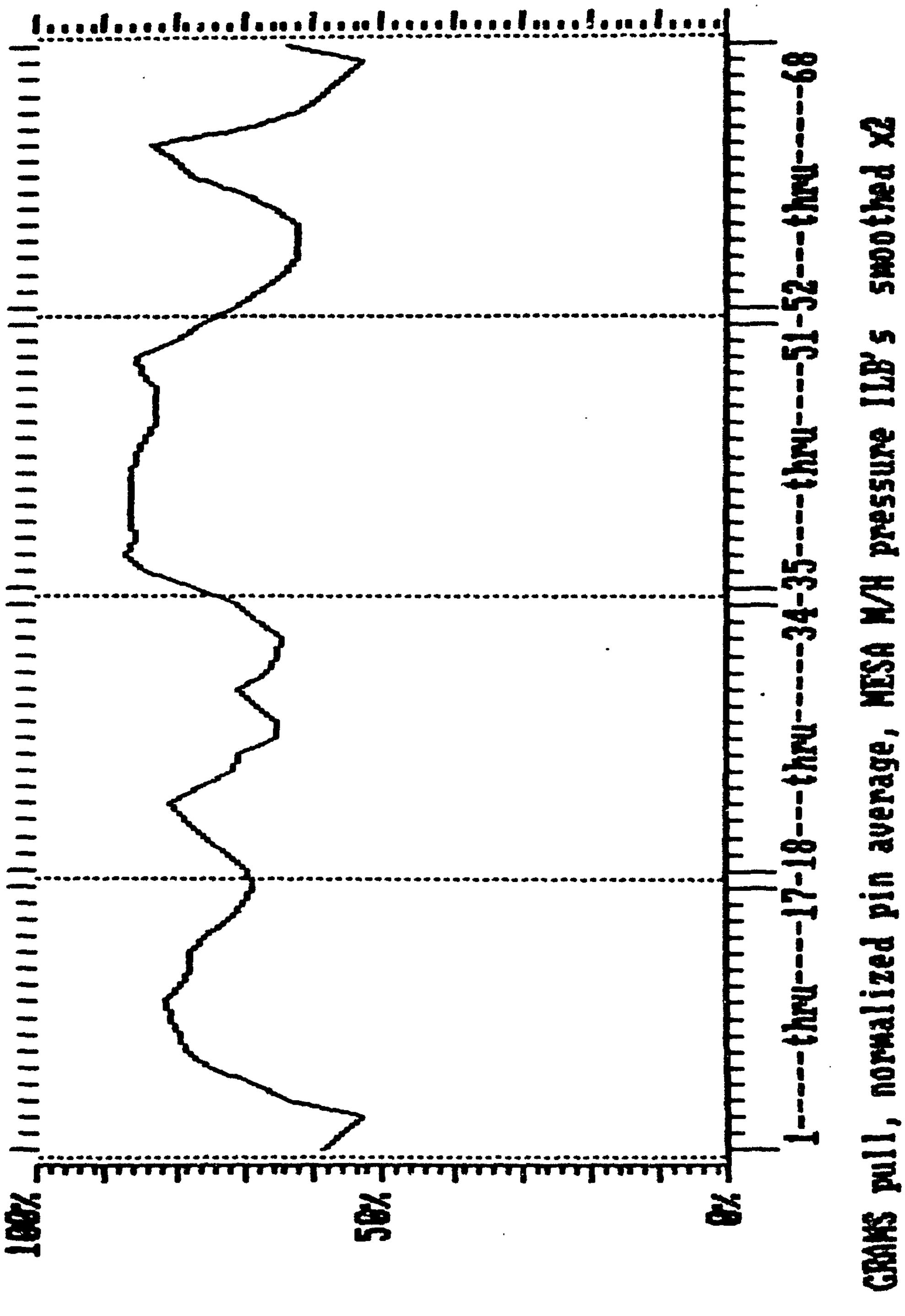


Figure B.4.5 Grams pull, normalized pin averages, MESA ILBs smoothed x2

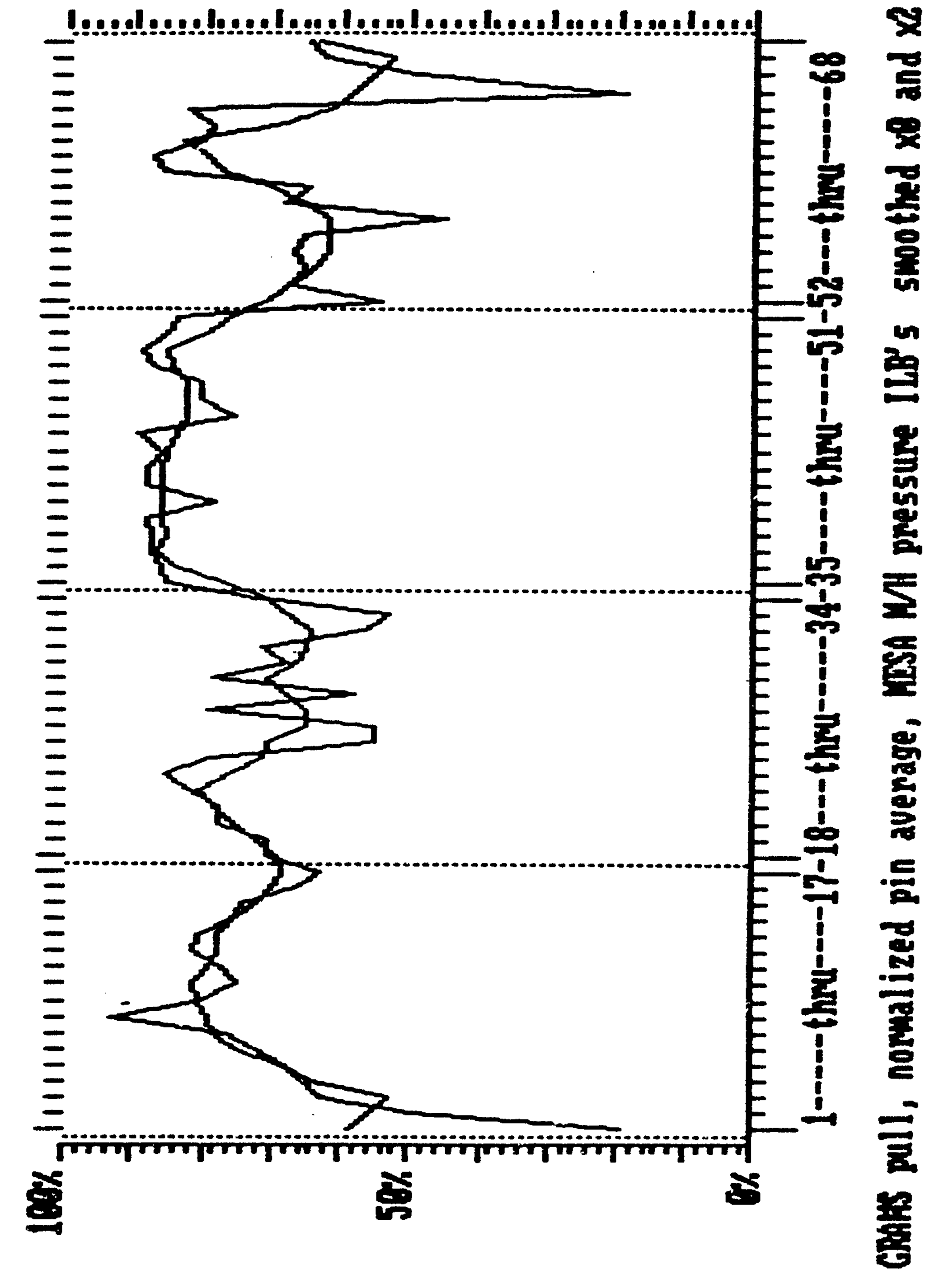


Figure B.4.6 Grams pull, normalized pin averages, MESA ILBs smoothed x0,x2

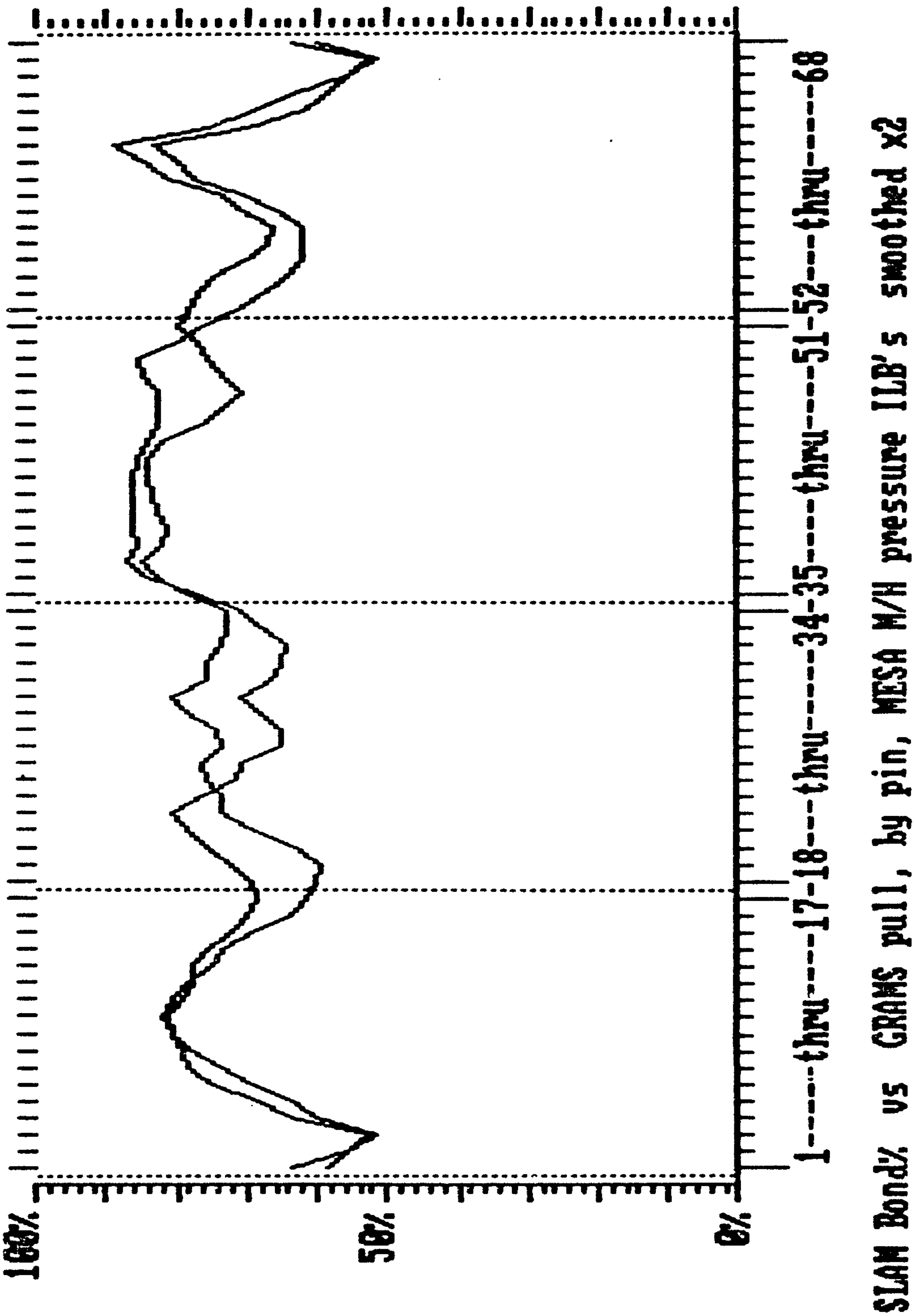


Figure B.4.7 SLAM Bond% vs Grams pull, by pin, MESA ILBs smoothed x2

APPENDIX C
Apparent Limit-of-Strength Curves
and
Probability (of a bond area meeting benchmark pull test) Curves

Two sets of curves are hereby presented based on the relationships found between SLAM and pull test values for the limited number of parts studied.

The curves referred to as limit-of-strength curves are those which would be had if there were no scatter in the relation between pull-test and SLAM Bond%; no damage to parts at any stage due to handling, no corner effect, no experimental error in the measurement procedures. These are idealized curves assessing what the ideal strength of a bond would be (all like-parts averaged together without benefit of normalization) based upon its SLAM bond percent. The reader may wish to ignore these as being unrealistically optimistic.

The curves referred to as probability curves are the actual set-derived probability of a bond of a measured SLAM bond percentage meeting or exceeding some level of pull test strength, if the bond were randomly selected from the same un-pulled samples, and then subjected to a pull test with the same variability of conditions present when the members of the experimental samples were pulled. As above, there is no benefit of normalization; thus, the strengths of intentionally weakly-made bonds is blended into the averaged data, and thus depresses it. As the curves move from left to right, fewer numbers are left in the population, therefore causing statistical bobble. At no time would an ideal curve decline in value when going from left to right (strength would not decline as bond area increased). The tendency to decline seen in some of these curves is due to statistical bobble in the increasingly sparse population; of the few members left in the population at the far right, single members which are anomalous due to handling damage, corner effect, etc. cause inappropriately high contribution.

Figure C.1.1 Apparent limiting strengths, SS ILBs

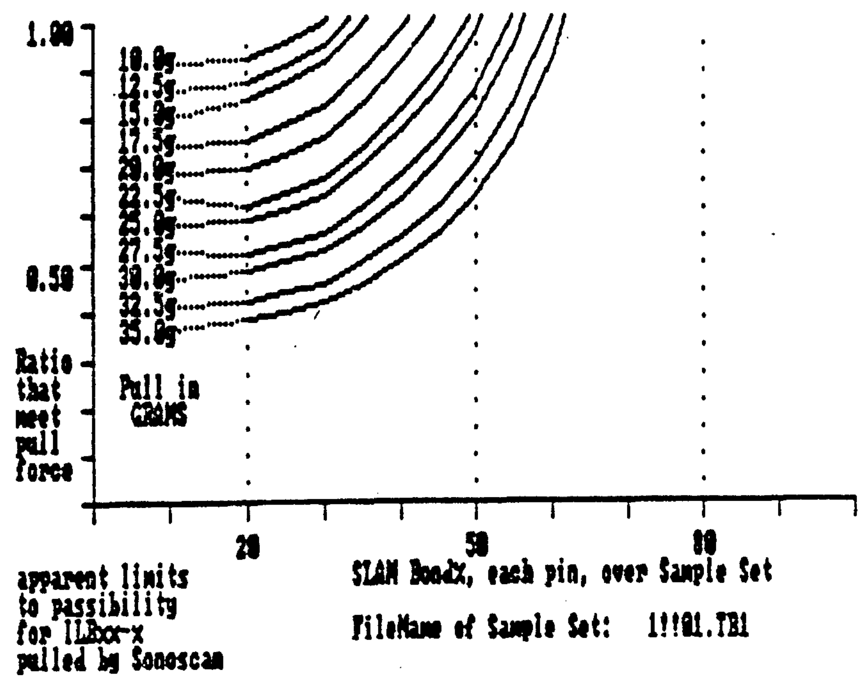


Figure C.1.2 Apparent limiting strengths, GTE ILBs

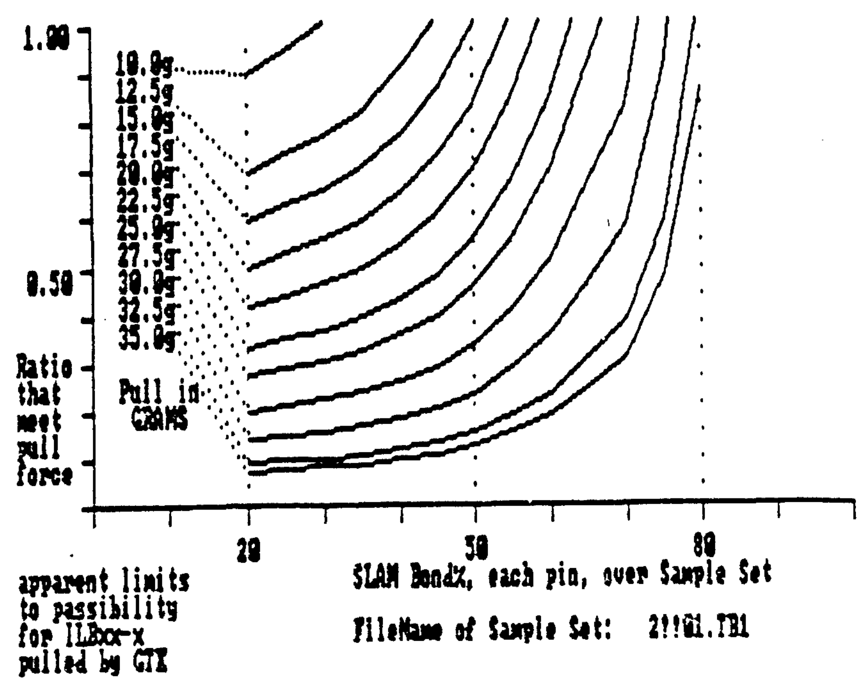


Figure C.1.3 Apparent limiting strengths, SS OLBs

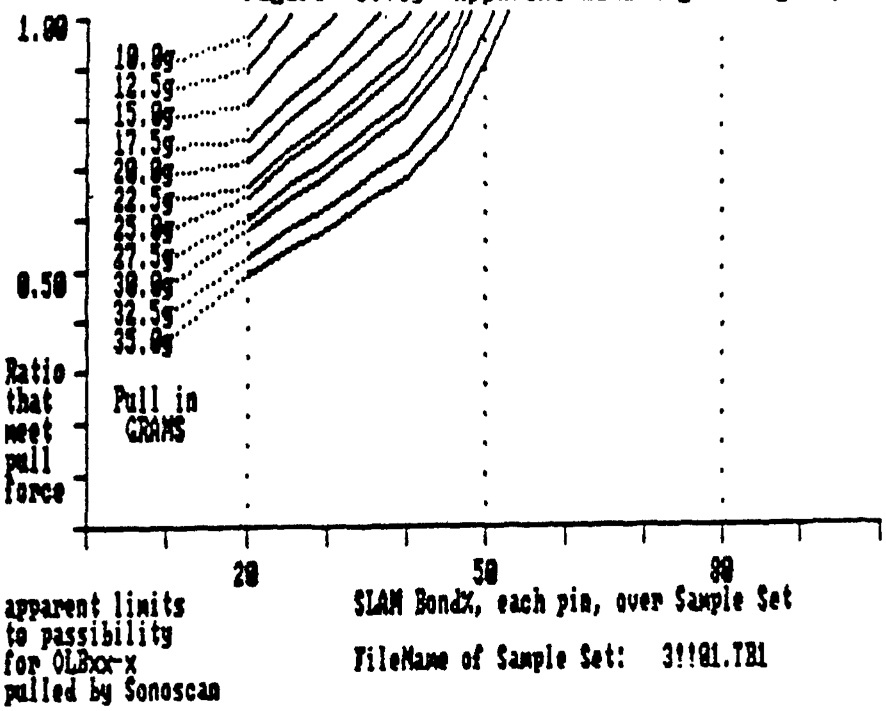


Figure C.1.4 Apparent limiting strengths, GTE OLBs

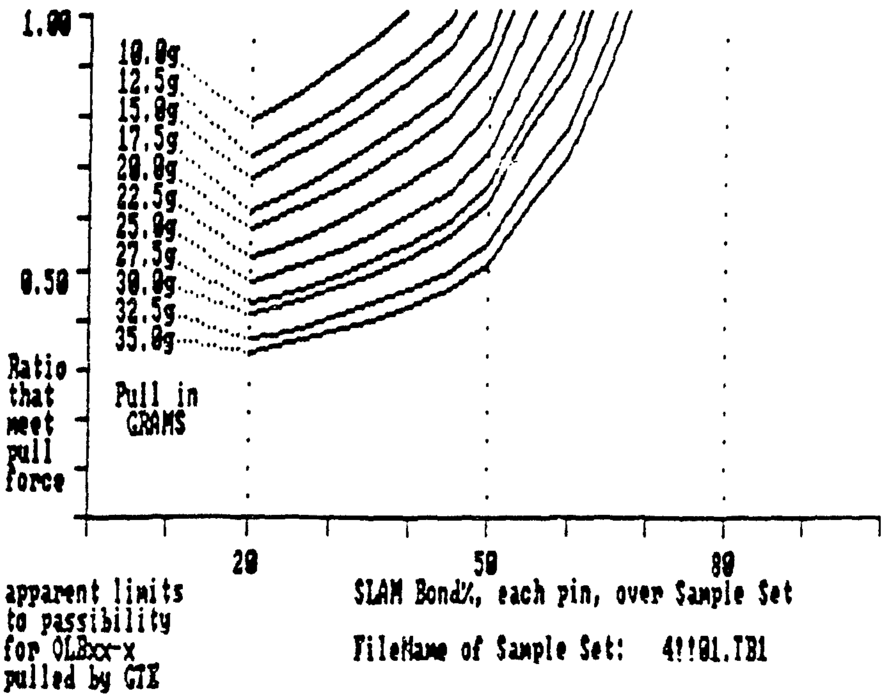


Figure C.2.1 Probability of meeting benchmark pull strengths, OLBs pulled by Sonoscan (no adjustment for corner effect)

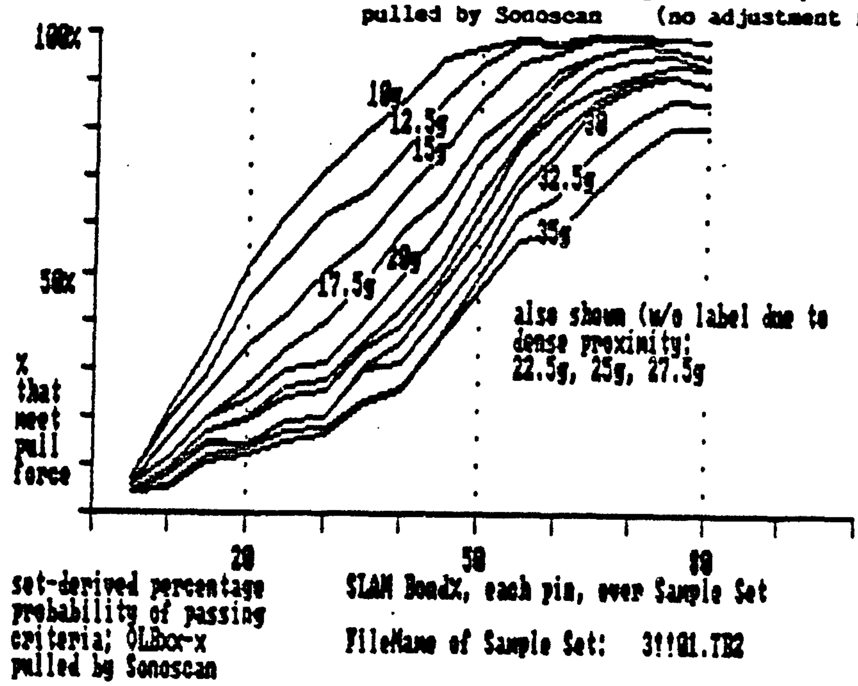


Figure C.2.2 Probability of meeting benchmark pull strengths, OLBs pulled by Sonoscan (small adjustment for corner effect)

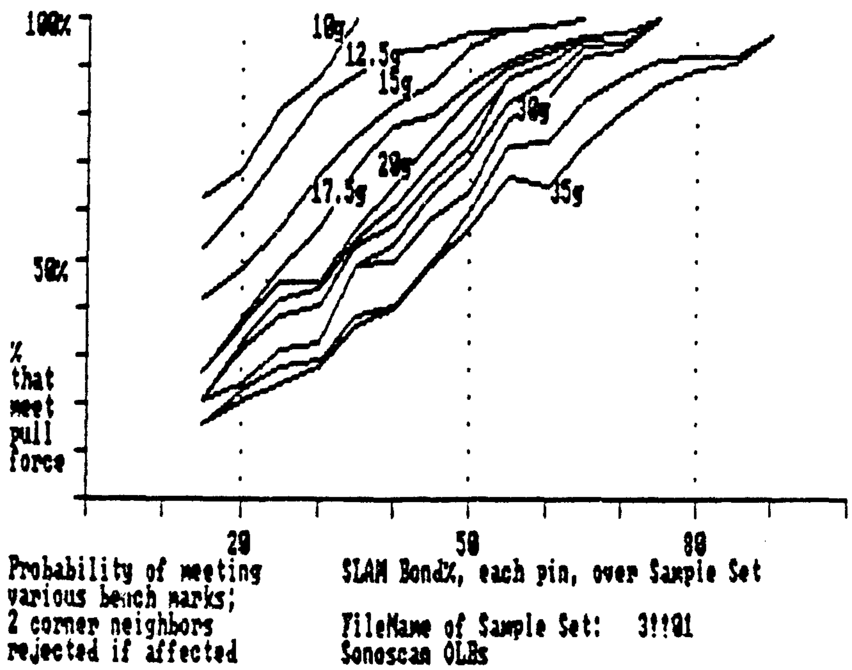


Figure C.2.3 Probability of meeting benchmark pull strengths, ILBs pulled by Sonoscan (no adjustment for corner effect)

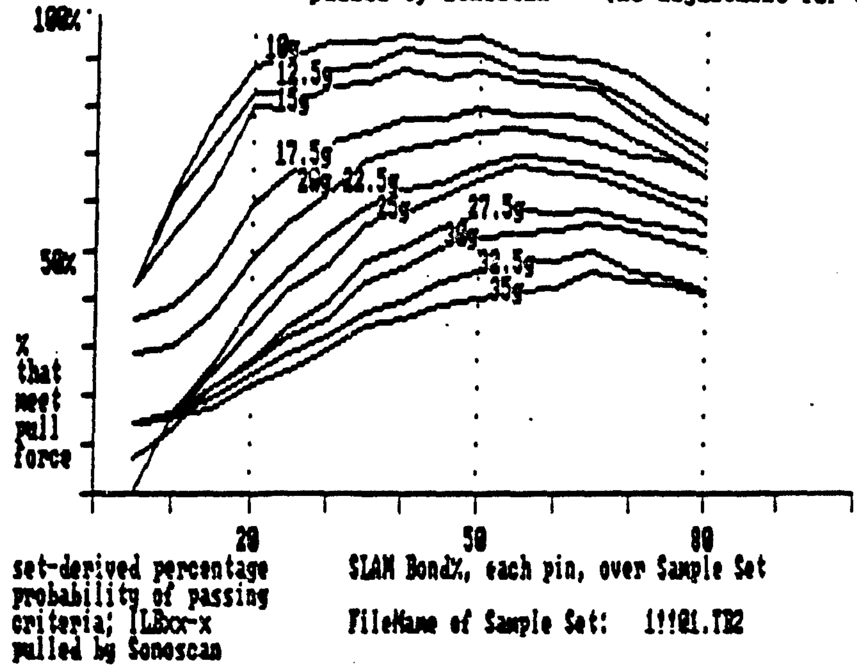


Figure C.2.4 Probability of meeting benchmark pull strengths, ILBs pulled by Sonoscan (small adjustment for corner effect)

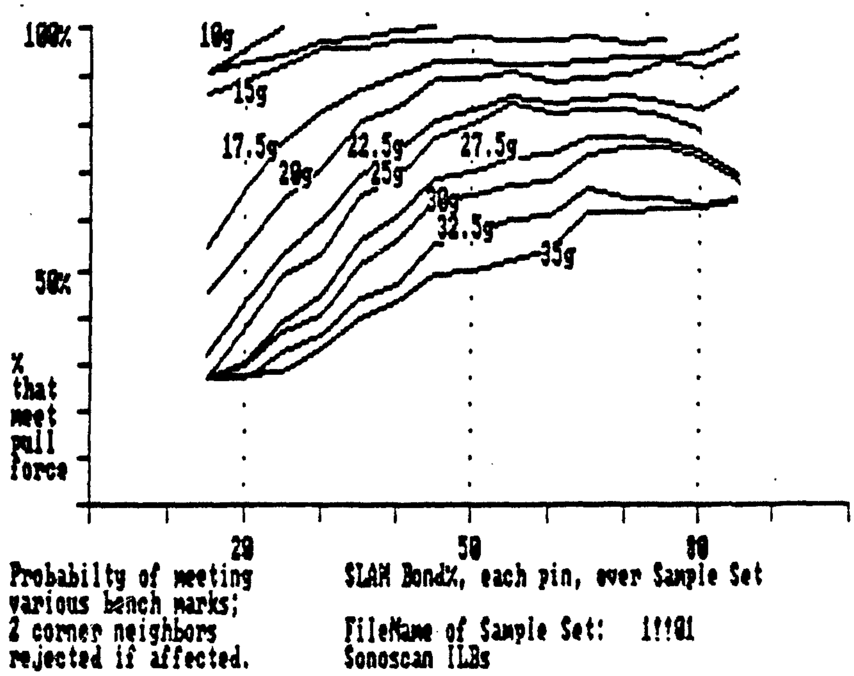


Figure C.2.5 Probability of meeting benchmark pull strengths, ILBs pulled by GTE (no adjustment for corner effect)

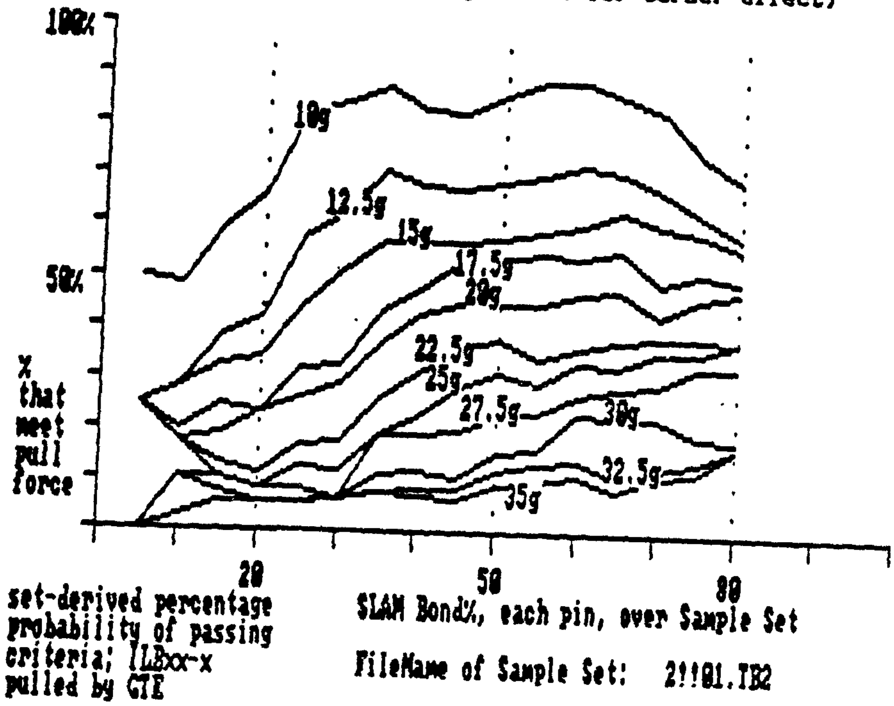


Figure C.2.6 Probability of meeting benchmark pull strengths, OLBs pulled by GTE (no adjustment for corner effect)

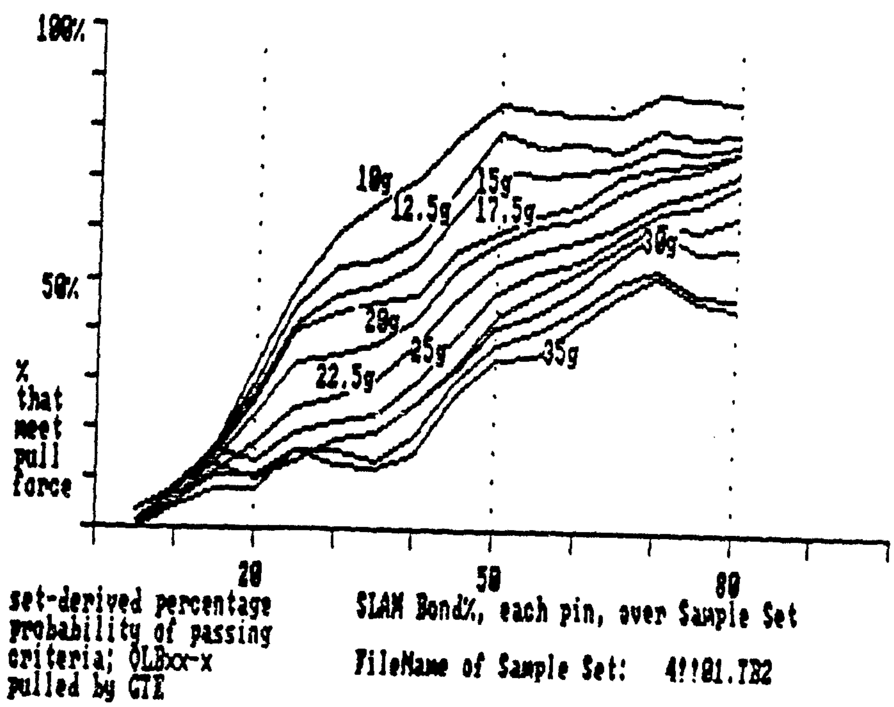
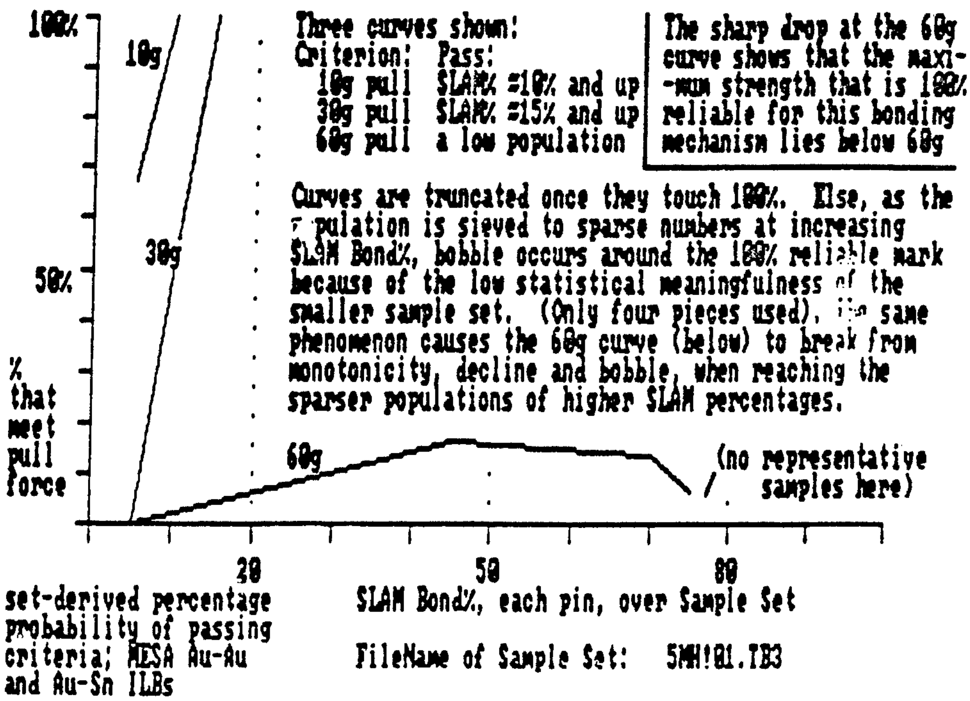


Figure C.2.7 Probability of meeting benchmark pull strengths, ILBs pulled by MESA (no adjustment for corner effect)



APPENDIX D

In Appendix D we present the draft of the MIL STD test method specification which is called for in the work statement for this contract. Our experience in this work has shown that innate metallurgical properties of the bond substance itself vary greatly; gold thermocompression and gold-tin eutectic formulations show a great deal higher strength than the lead-tin solder formulations, and within the lead-tin solder formulations, significant metallurgical difference exists between the OLB and ILB compositions. Furthermore, innate metallurgical strength seems to vary greatly in the solder samples due to temperature during the bonding condition. Therefore, we also offer a method for the evaluation of this innate metallurgical strength as an adjunct to assessment of the bond quality by the use of SLAM inspection.

These two draft proposals follow, and are titled:

ULTRASONIC INSPECTION OF TAB BONDS

-and-

QUALIFICATION OF BOND METALLURGICAL STRENGTH

METHOD xxxx

ULTRASONIC INSPECTION OF TAB BONDS

1. PURPOSE

The purpose of this method is to detect unbonded and insufficiently bonded sites in TAB (Tape Automated Bonding) devices in the open package condition, through the measurement of bond area by means of Scanning Laser Acoustic Microscope (SLAM) techniques. It establishes methods and criteria for ultrasonic inspection of these TAB semiconductor devices.

NOTES:

A) For various metallurgical constitutions, absolute strengths expressed as pull strengths per unit area of bond differ. A scalar equivalency must be established for each alloy and process, to relate bond area to anticipated bond strength.

B) The term TAB bond in this document refers to one of the multiplicity of bonds, inner lead (ILB) or outer lead (OLB) formed by a Tape Automated Bonding (TAB) process. In the case of ILB, it refers to that area of the device defined by the intersection of the beam lead, the semiconductor bonding pad area, and the the contact outline of the thermode or fixture performing the bond, in the horizontal plane, and refers to all interfaces within that area between the semiconductor die surface and the beam lead. In the case of OLB, it refers to that area of the device defined by the intersection of the beam lead, the substrate bonding pad area, and contact outline of thermode or fixture performing the bond, in the horizontal plane, and refers to all interfaces within that area between the substrate surface and the beam lead.

C) The terms ultrasonic inspection and SLAM as used in this document refer to the process and instrument performing high frequency ultrasonic inspection and produce grey-scale images of the internal features of devices by means of scanning laser acoustic microscopy, and by which bond area measurement may be performed.

2. APPARATUS

The apparatus and materials for this evaluation shall include:

A) Ultrasonic imaging equipment of the scanning laser acoustic microscope type, of frequency and resolution sufficient to penetrate the bond area and render an image which discloses the size and shape of the bond

area with a linear dimensional allowance no greater than 20% of a bond dimension. Frequency is dictated by consideration of the wavelength of sound in the materials and the limit of resolution. Whereas lower frequencies have been used for inspection of larger-scale device types, the present size of TAB sites requires frequencies of from one hundred to several hundred megahertz.

B) A visual output/storage device. A method of producing, displaying, and storing a scale image of adequate grey-scale range (minimum of 64 levels) shall be used. Such device may include a grey-scale printer/plotter, or preferably CRT display with an image digitizer capable of rendering images in digital code for bulk media storage and retrieval, and algorithmic processing and evaluation. The images so stored shall be suitable for manual, or preferably, automated analysis. The output device shall be capable of producing and storing the images to a spatial and grey-scale resolution at least equal to the resolution of their acquisition by the ultrasonic imaging equipment. The output/storage device must be capable of presenting, storing, and retrieving image label information.

3. PROCEDURE

The equipment used shall be adjusted as necessary to obtain satisfactory images of good contrast to achieve maximum image detail within the sensitivity requirements of the bond type being examined. The appropriate operator methodology will be used to insure adequate positioning and insonification (irradiation by ultrasound) of the device for purposes of producing its image. Additional protocols will be followed as required. The normal intrinsic strength of the bond metallurgy shall be known and established, and the metallurgy of the devices to be tested should be qualified as in agreement with that strength.

(For a method of qualification, refer to proposed MIL STD 883C Method xxxx "Qualification of Bond Metallurgical Strength"

3.1 Calibration of the Instrument

When specified, at least one device, of the type and construction to be tested shall be available to set up the ultrasonic inspection equipment and peripherals. The device may be a scrap non-operational device with TAB bonded leads which will be used to identify device landmarks and ensure the equipment is properly functional.

3.2 Labeling and identifying

The devices tested and the image records made of them shall be labelled in a standard format to include the

following information:

A) Device manufacturer's name or code identification number.

B) Device type or part number.

C) Production lot number and/or inspection date code lot number.

D) Ultrasonic image view number and date; to include description or code for the region or bond number(s) viewed.

E) Device serial/cross reference number if applicable.

F) Ultrasonic operator identification.

3.3 Serialized devices

When device serialization is required, each device shall be readily identifiable by a serial number, and this serial number must be included in a form readable in the stored image. In the event of a skipped piece in the serialization, a blank space representing the skipped piece, and labelled with its serial number should appear in the storage medium. In the event of a large contiguous range of skipped pieces, a similar blank space advising of the range of pieces skipped should appear in the storage medium in place of the large physical space of the many skips.

3.4 Data Back-up

When required, data back-up shall be specified from a choice of multiple floppy disk, multiple track data tape, or a video format tape, or other options having sufficient volume, resolution, speed, and reliability to suit the requirements for storage and labeling.

3.5 Mounting

The devices shall be mounted for ultrasonic inspection in a fixture which insures correct positioning in all dimensions, and adequately safeguards the potentially fragile bonds from mechanical contact with any substance other than the coupling fluid. Positioning thereafter must continue in a fashion which continues the above conditions, and furthermore exposes each inspected bond area to the correct acoustic environment and portion of the instrumental field.

3.6 Angle of Insonification

The angle of insonification must be specified by prior analysis, and if the mounting fixture is goniometrically agile it must be set to the correct angle by adjustment or selection.

3.7 Conditions of Operation

Adjustments, selections, options, and settings used in the performance of the ultrasonic inspection must be recorded if they are of a nature critical to the proper operation of equipment; not to be recorded are those casual adjustments which are done as an obvious matter of course, and the performance of which are guided by such rules as trimming for maximum, minimum or optimum, and which are not controlled by calibrated interfaces.

3.8 Operating Personnel

Operating personnel shall have a basic familiarity of the nature of sound and the use of ultrasonic instruments in the inspection of devices. They shall be specifically trained and certified in the operation of the ultrasound and peripheral equipment used so that defects revealed by the method can be validly interpreted and compared with applicable standards.

3.9 Reports of Inspection

For Class S devices, or when specified for other device classes, the manufacturer shall furnish inspection reports with each shipment of devices. The report shall describe the results from the ultrasonic inspection, and list the purchase order number, or equivalent identification, the part number, the date code, the quantity inspected, the quantity rejected, and the date of the test. For each rejected device, the part number, the serial number when applicable, and the cause for rejection shall be listed.

3.10 Acoustic Micrograph and Report Retention

When specified, the manufacturer shall retain a set of the ultrasonic images and a copy of the inspection report, for the period specified.

3.11 Examination and Acceptance Criteria

Once the manufacturer has established the total bond area to be sought, based upon studies of the device to be bonded, and the inclusion of a prudent excess margin, then the following shall be condsidered the minimum bond area percentage:

A) In the case of solder bonds of lead-tin alloys a bond area percentage of 75 percent of the total bond area shall be considered minimum.

B) In the case of gold-tin eutectic and gold-gold thermocompression, a bond area percentage of 50 percent of the total bond area shall be considered minimum, except in the case of lead misalignment; when lead misalignment is a contributing factor a bond area percentage of 75 percent shall be considered minimum.

In the examination of devices, the following aspects shall be considered unacceptable bonding, and devices which exhibit any of the following defects shall be rejected:

A) A bond having a total bond area less than the minimum bond area. The failure may be caused by any reason, including lateral or longitudinal misalignment.

B) A bond meeting the minimum bond area, but with this area being discontinuous so that no single bonded area meets or exceeds the minimum bond area.

4. SUMMARY

The following details shall be specified in the applicable acquisition document:

A) Number of views to the taken by SLAM inspection of each piece or bonding site, per 3.10, if other than one view.

B) Markings of devices, or labelling of images, if other than per 3.2, or special markings of devices to indicate that they have been ultrasonically imaged, if required.

C) Defects to be sought in the devices, and criteria for acceptance or rejection, if other than in 3.11.

D) Image and report retention when applicable (see 3.10).

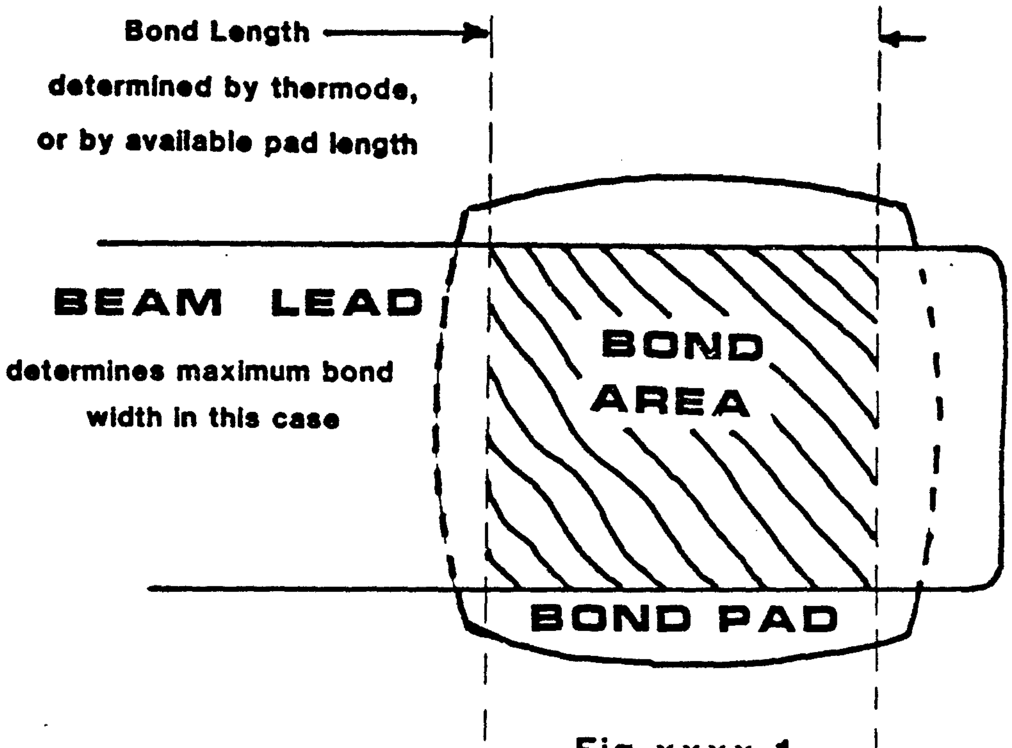


Fig xxxx.1

ACCEPT

contains minimum area

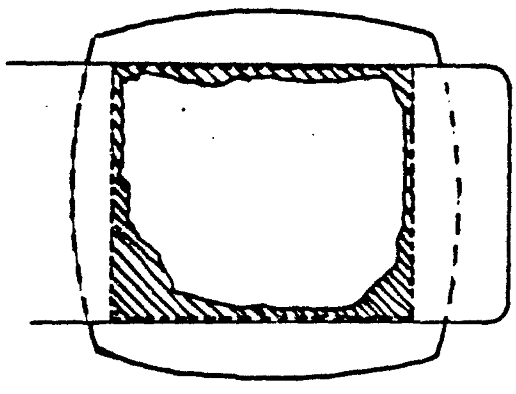


Fig xxxx.2

REJECT

<minimum area

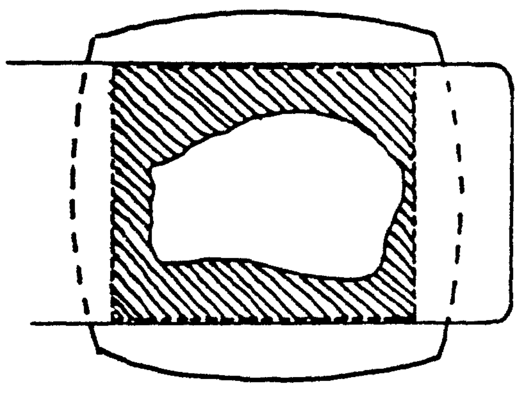


Fig xxxx.3

REJECT

minimum area, but not

in any one continuous space

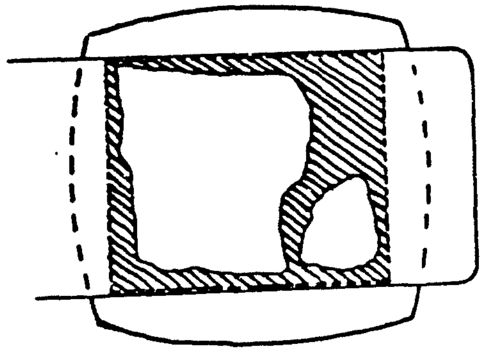


Fig xxxx.4

REJECT

< minimum area due to

lateral misalignment

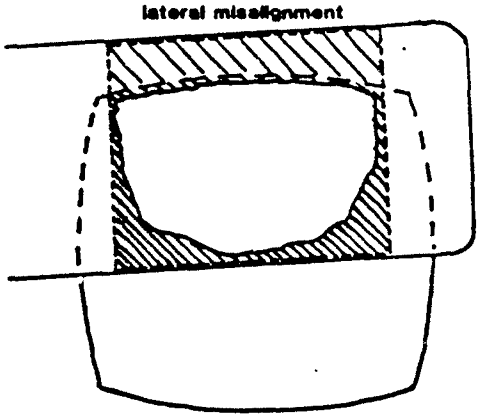


Fig xxxx.5

REJECT

< minimum area due to

longitudinal misalignment

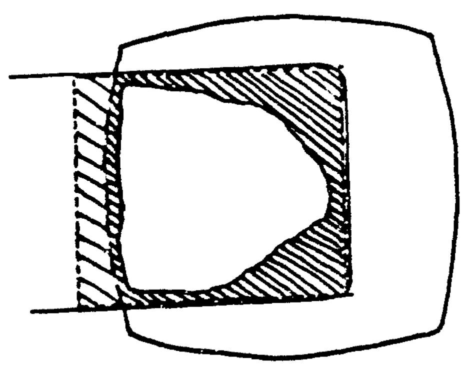


Fig xxxx.6

MIL-STD-883C

METHOD xxxx

QUALIFICATION OF BOND METALLURGICAL STRENGTH

1. PURPOSE

The purpose of this method is to establish that a given range of samples from a production run of a TAB (Tape Automated Bond-ing) process meets the intrinsic metallurgical character, in terms of strength per area, established for that bond type. This value is referred to as the specific metallurgical strength of the bond, for purposes of this discussion, and is used as an adjunct to other evaluation methods, such as scanning laser acoustic microscopy (SLAM) when non-destructively inspecting bonding by processes such as the tape automated bonding (TAB) process (see MIL STD 883C Method xxxx).

NOTES:

A) For various metallurgical constitutions, relative strengths expressed as pull strengths per unit area of bond differ. A scalar equivalency must be established for each alloy and process, to relate bond area to anticipated bond strength.

B) As it can be shown that a pull test does not give a direct relationship to strength per area, a pull test as employed herein serves to establish relative standards rather than absolute ones.

C) The establishment of the expected strength for a given type of bond, metallurgy, and process should be done in a manner which recapitulates the selection processes described below, but which uses a large plenitude of sample pieces established by alternate means as meeting metallurgical character.

2. APPARATUS

The apparatus and materials for this evaluation shall include:

A) A pull test machine equipped with a method for apprehending device beam leads of a size and spacing appropriate to the devices undergoing test.

B) Stereomicroscope capable of an optical magnification of at least ten diameters, or some other method, manual or automated, capable of aiding in the apprehension of the lead without the causing of incidental damage.

C) The pull test machine shall be capable of an essentially vertical pull (in a direction perpendicular to the plane containing the bonding area). This may be accomplished by apprehension with a tweezer mechanism, or by a hook placed as immediately close to the bond site as possible.

D) A method of independently determining the bond area of the bonds of selected test samples. This method may comprise optical metallographic inspection after the destructive pull testing is completed, or

may be done in a more automated fashion by means of scanning laser acoustical microscopy (SLAM; refer to MIL STD 883C Method xxxx) prior to performing the destructive pull testing. The selection between these methods necessarily implies a difference in the order of procedure.

3. PROCEDURE

3.1 Sample Selection

It shall be determined whether the production run or portion thereof to be evaluated is continuous or discontinuous. For the present purposes, a production run is discontinuous if the process variables must change to attain or lose equilibrium at the beginning or end of the period of the production run to be evaluated. A continuous production run by contrast is one wherein the process variables are in equilibrium throughout the evaluated portion of the run. For a continuous or sufficiently long discontinuous run, there shall also be determined the time constant, if any, of any drift in process conditions, and this shall, for the present purposes, comprise the expected drifting time.

For a discontinuous production run, the time required to attain equilibrium in all process conditions shall be determined, and parts produced during this time shall be dummy parts, or parts subject to conditional rejection. No part from this pre-equilibrium state shall be selected as a sample for purposes of this evaluation.

Samples shall be drawn in the following manner:

A) For a short discontinuous run, at least two samples shall be taken. One shall be the second part produced after the equilibrium of process conditions has been obtained. The second sample shall be taken from the last third of the production run, but shall not be the last piece produced.

B) For a continuous or sufficiently long discontinuous production run, additional samples shall be taken at the periodicity determined to be the expected drifting time of process conditions.

C) For a continuous or sufficiently long discontinuous production run having an expected drifting time that is long with respect to the period of the run that is being evaluated, a third sample shall nonetheless be taken, from the middle third of the run.

D) Parts taken may, for purposes of economy, consist of electrical failures, or deliberate dummy samples. If they are of this nature however, they must conform in all ways to the bonding geometries, positions, sizes, and materials of the main production run. If an electrical failure is chosen as a sample, the mode

of failure must be known to not include any elements related to the bonding process.

3.2 Bond Area Determination
The choice of method for bond area determination will dictate procedure. If SLAM inspection is elected, it must be performed prior to pull test. If optical metallographic examination is elected, it must be performed subsequent to pull test.

3.3 Pull Test
Each sample piece selected shall be exhaustively pull tested, recording the lead position number, the yield strength, and any anomalies encountered during each pull, such as tester failure, or part failure at any point other than the bond area, or any condition encountered that might tend to invalidate the test data.
For each sample piece, separately and independently from the others, the following culling process is performed:

A) Any lead noted to have an anomalous condition during the pull test is discarded from the data set. If more than ten percent of the total number of leads is thusly discarded, a new sample must be selected.

B) To ensure that the highest strength standard is applied, presumably from the bonds of highest bond areas, the lowest pull test values are progressively discarded from the data until one half of the total number of bonds sites (to the nearest whole number in the case of odd numbers) remains.

C) To elimnate torsional, geometric, and incidental damage effects, this best-half set is further culled to a best-quarter set by progressively eliminating those leads of geometry and position most inherently affectable; i.e. those with the most non-straight geometries, those closest to the corners of the lead frame, and those closest to gaps (absences of more than one lead) in the lead frame. This shall be done in a manner progressing from most affected to least affected, without regard to completion of a given side or sector of the part, and without regard to the relative population left by previous culling, until the least-affected one quarter of the total number of bonds sites remains.

3.4 Confirmation of Metallurgical Character
The data from each sample is then independently analyzed to establish that its metallurgy meets the expected value. This is done by the following process:

A) The sum of the pull strength values remaining in the data set (best quarter) of that sample is found, and divided by the number of sites that comprise one quarter of the bond sites. This value is the average pull test strength.

B) The sum of the bonded areas of all the sites that remain in the data set (best quarter) is also found, and the average similarly obtained.

C) The quotient of average strength over average area is found, and comprises the specific metallurgical strength of the bonds at the various moments of the evaluated production run.

Bonding may be deemed to be metallurgically sound if every sample meets or exceeds 80% of the specific metallurgical strength determined at a prior time to be acceptable for the present type of bond.

3.5 Reports of Inspection

For Class S devices, or when specified for other device classes, the manufacturer shall furnish inspection reports with each shipment of devices. The report shall list the purchase order number, the part number, and the date code. The report shall describe the results of the metallurgical evaluation, including the number of devices sacrificed, and the specific metallurgical strength found for each sample.

3.6 Data and Report Retention

When specified, the manufacturer shall retain for the specified time a copy of the inspection report, original data from the pull test, and data from the bond area determination in the form of optical micrographs in the case of optical metallography, or stored images in the case of SLAM evaluation.

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